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ELEMENTS
OF
CHEMISTRY.

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ELEMENTS

OF

CHEMISTRY.

BY

John
J. MURRAY,

LECTURER ON CHEMISTRY, MATERIA
MEDICA, AND PHARMACY.

VOLUME I.

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P R E F A C E.

THE present publication is an outline of a course of Lectures on Chemistry, delivered by the Author, and is published principally with the design of facilitating the study of the Science to those to whom these Lectures are addressed.

Convinced that a mere enumeration of the subjects which the course includes, would be very imperfectly adapted to that design, he has endeavoured, by a concise statement of leading facts and principles, to render this abstract of more general utility, and to frame a work which may serve as an elementary introduction to Chemistry. With this view, he has endeavoured

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deavoured to render it every where simple and perspicuous; and he trusts, that the systematic arrangement he has adopted, will be found calculated to exhibit to advantage the elements of the science,

Convinced also, that the principal object of the teacher ought to be to illustrate and establish the general principles and most important applications of the branch of knowledge of which he treats, he has allotted a comparatively large share of attention to these subjects; an extension of his plan, which requires less apology, as the theoretical part of chemistry is in general too briefly noticed in elementary works. In conformity to the original design of this publication, he has also stated the principal arguments on several important Chemical questions, at present the subject of dispute, in the discussion of which he is obliged, in the course of his lectures, to engage. It may be necessary for him to remark, with respect to the
 opinions

opinions he may have offered on these and some other subjects, that, as in this abstract they must be very concisely stated, they may appear to less advantage than when accompanied by those illustrations and collateral arguments which contribute to their support. For this unavoidable imperfection, candid criticism will make due allowance.—In the discussion of one of the most important of these questions, that respecting the nature of radiant caloric and the heating power of solar light, he is flattered to find, that the conclusions which he has deduced from the valuable experiments of Dr. Herschel in the 2d part of the Philosophical Transactions for the present year, are the same as those which the Doctor has established in the sequel to his papers, in the 3d part of the same volume, published while the last sheet of this volume was in the press. These conclusions are, that radiant caloric is entirely different from light, and that visible light has no heating power ;

power ; and the same opinions, supported by arguments somewhat different, were delivered by the Author in his last course of Lectures, and are briefly stated in this treatise.

It is perhaps scarcely necessary to add, that every care has been taken to comprise in these Outlines the most recent chemical discoveries, and, on every subject, to relate the facts with that accuracy which is indispensable to give value to an elementary work.

Edinburgh, 21st April, 1801.

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ERRATA.

Page 73, line 25, Dele *may*.

— 144, — 16, After *chemical* add *attraction*.

— 272, — 18, For *produce* read *produces*.

INTRODUCTION.

CHEMISTRY is the principal branch of that department of Physical Science which investigates the actions exerted between the minute particles of matter. Besides the general tendency which bodies, even in the largest masses, and at the greatest distances, have to approach, until they come into apparent contact, the exertion of which gives rise to all those sensible motions that compose so important a part of the economy of the universe ; there exists a similar power of attraction between the minute ultimate particles of matter, which tends to bring them into intimate union. This power exerted between the particles of heterogeneous bodies, is termed Chemical Attraction, or Affinity. From its exertion, different bodies, placed under certain circumstances, act upon each other, so as to form substances distinguished by the possession of new
B properties ;

properties; and the investigation of such actions constitutes by far the most extensive and important part of the Science of Chemistry.

There is another power, that of Heat, or Caloric, likewise exerted between the minute particles of matter; which tends not to unite them, but to place them at greater distances from each other. It expands bodies, renders them fluid, or converts them into vapour; and it always modifies, by its action, the exertion of chemical attraction. Its properties, therefore, the effects it produces, and the laws by which it acts, are subjects of chemical investigation.

Such is the nature of Chemical Science. It investigates the changes arising from these two powers, Chemical Attraction and Caloric; and determines the laws by which these changes are regulated.

Chemical Attraction, the first of these powers, is clearly distinguished, by its mode of operation, from the other species of attraction with which matter is endowed. The Attraction of Gravitation is exerted between large masses of matter, and at the greatest distances: the phenomena it produces

produces arise merely from changes of place in the bodies operated on, and are accompanied by no change of properties, nor any permanent union. The Attraction of Cohesion, or Aggregation, is exerted between particles of the same kind of matter, and forms aggregates possessed merely of the properties of the particles of which they are composed. Chemical Attraction is necessarily exerted between the particles of *different* kinds of matter: in order to its being exerted, these particles must be nearly in contact; they are so intimately united as to form a homogeneous mass, indestructible by mechanical means; and properties more or less new are always acquired. It is to chemical union that the vast variety of substances existing in nature owe their origin, as they are all formed from the combinations of a few simple principles.

The simplest case of the exertion of chemical attraction, is that where two bodies, placed in contact with each other, form a direct union. In chemical language, this is termed Combination: the substance produced a compound; and the bodies from which it has been formed, its constituent principles, or component parts. These are retained in union, by a force
of

of attraction, which in different bodies is very different; but which is always such, that the compound resists any mechanical force employed to disunite its principles; and can be decomposed only by the exertion of a superior chemical power. The properties of a compound are in general very different from those of the component parts.

Chemical Union may be illustrated by the following example: If a quantity of any substance, not soluble in water, or very sparingly so, suppose it to be the earth termed Magnesia, be diffused in a portion of that fluid, a white turbid mixture is formed, which, upon standing sufficiently long at rest, deposits a powder; the fluid above remaining transparent. In this case, no chemical action has taken place; the magnesia and the water have been merely mechanically mixed, but have not combined, since on standing they separate, each obeying its specific gravity.

But suppose that to the mixture of Magnesia and water, a small quantity of another fluid, termed Nitric acid, be added, a change very quickly appears. The turbid mixture becomes transparent, and the properties of the acid, and of the magnesia,

magnesia, are entirely lost by their entering into chemical union.

It is this intimate union, this formation of a new kind of matter, in which the particles of the former substances can no longer be distinguished, and in which new properties are acquired, that characterizes chemical combination.

When a compound is formed, if left to itself, it remains unchanged, its principles having no tendency to separate. But if it is placed under certain circumstances, in contact with another body which has an attraction to one of its component parts, superior to the attraction by which these are united, the two between which the attraction is strongest combine, and the other is separated. Thus, if to the above compound of Magnesia and Nitric acid, the substance termed Potash is added, it combines with the Nitric acid, and the Magnesia is deposited with its properties unchanged. In the language of Chemistry this is termed Decomposition, and it is as extensive in its agency as Combination.

In many cases, both of Combination and Decomposition, chemical action is rendered still more striking.

striking, by the phenomena which it exhibits while it is taking place; as by the production of heat or light, by the extrication of air, or by change of colour, of form, or of other properties in the bodies combined.

The great objects of chemical research are to trace the various combinations existing in nature, and those capable of being effected by art. In these investigations, the Chemist, proceeding through innumerable decompositions, ultimately arrives at a few bodies, which he is unable farther to decompose, or to resolve into two or more component parts, so as to ascertain that they are compounds. These therefore he considers as Simple Substances, or Elements, which, by their various combinations, form every other kind of matter that can be produced. He traces them through all their combinations, observes the phenomena by which these are accompanied, the laws according to which they are produced, the properties of the compounds which are formed, and the farther combinations into which these compounds are capable of entering. To such investigations, which form the principal part of Chemical Science, we are indebted for our knowledge of many of the phenomena of nature, and the

INTRODUCTION.

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the establishment and improvement of many of the arts. -

The other department of Chemistry is that which relates to the properties and modes of action of Caloric. It of course comprehends the consideration of expansion, fluidity, and vaporization; of the manner in which Caloric is transmitted through bodies; of the quantities of it which they contain; of its extrication and absorption; and of its influence on the exertion of chemical attraction.

The APPLICATIONS of Chemistry, and its Connections with the other Sciences, are extensive and important; many of the phenomena which nature presents to our observation, arising from the chemical actions of various substances on each other, and many of the arts being nothing more than a series of chemical processes.

Thus, in the general economy of nature, the temperature of the globe, and the causes of its variation; the evaporation of water; the formation of clouds, rain, dew, snow; the appearance of meteors, and other changes produced in the atmosphere; the corruption and amelioration of the
the

the air ; the temperature and impregnations of springs ; the formation of minerals ; the disposition of the strata of the earth ; these are, more or less, the result of chemical action, and are therefore to be explained on chemical principles.

To natural history, Chemistry lends the most essential aid. It in particular enables the Mineralogist to distinguish and arrange those productions of nature which it is the object of his science to investigate.

In the animated world, chemical influence is not less perceptible. It explains the growth and nutrition of organised beings, and the formation of all their products ; and is often able to point out the causes of those derangements which their functions suffer from external agents. Hence the intimate connections which Chemistry has with medicine, and with animal and vegetable Physiology.

Pharmacy is merely a branch of this science ; its object being the preparation of substances employed as remedies, and these being in general the results of chemical processes.

With

With the Arts, Chemistry is not less extensively connected than with the Sciences. Different substances act upon each other when placed in certain circumstances, so as to produce certain effects, which, were these circumstances not attended to, would not take place. The arrangement, and management, in particular cases, of such circumstances, so as to produce these effects, constitute the various chemical arts.

Agriculture, the first of the arts, is nothing more than the just application of the principles of vegetable physiology, so as to obtain, at the least expence, the largest produce from useful plants. Chemistry explains the growth and nutrition of vegetables, discovers the modes of action of manures, teaches their proper application, and discovers the nature of any soil.

In the application of the products of Agriculture, the influence of this Science is still to be traced. The arts of making bread, of brewing, of distilling, of making starch, sugar, vinegar, of varnish-making, of bleaching, and of dyeing, are, strictly speaking, nothing more than chemical processes. Such also are those arts which apply to useful purposes the products of the animal

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kingdom ; as tanning, making of soap, of glue, and many others.

Metallurgy, or the art of extracting the metals from their ores, that of purifying, of forging, and of casting them ; that of making metallic alloys, or metallic compounds for painting and dyeing, the processes of glass-making and enamelling, and the fabrication of pottery and porcelain, are likewise arts the principles of which are immediately dependent on Chemical Science.

Lastly, various applications to purposes of utility are likewise made of the effects attending chemical action ; as of the expansive force of steam in the steam engine, or that of the airs which are disengaged in the detonation of gunpowder.

In arranging this vast body of knowledge, either directly chemical or connected with Chemistry, various plans have been followed. These may in general be reduced to two kinds ; one, in which the arrangement is founded on the physical and chemical properties of bodies ; the other in which their chemical composition only is regarded.

Of

Of the first kind is the old division of the chemical agents, into Salts, Earths, Inflammables, Metals, and Waters; each of these classes containing a number of substances, distinguished by the possession of some common properties, and being subdivided into orders and genera, in which the same principle of arrangement is observed.

It requires no minute investigation to discover the imperfections of this method; for, as the principal object of chemical investigation is to discover the composition of bodies, and their combinations with each other, it is evident that any arrangement in which the composition is disregarded, must be imperfectly calculated to facilitate the study of the Science. Simple and Compound substances will be placed in the same class: in whatever order the classes be distributed, compounds will frequently fall to be considered before the simple bodies of which they are formed, by which every advantage of arrangement is lost: and, lastly, several of the most important chemical agents are isolated in their properties, and cannot with propriety be brought under any of the established classes.

In that arrangement founded solely on the
chemical

chemical nature or composition of bodies, these disadvantages are avoided. The Simple substances are first considered, and afterwards the Compounds which they form; and these may be so arranged, that, on the one hand, anticipation shall not be necessary; and on the other, every substance may be fully described.

On this plan is founded the arrangement which is to be observed in this work.

CHAP.

CHAP. I.

OF THE CHEMICAL OPERATIONS AND APPARATUS.

THE great object of Chemical investigation is to discover the composition of Bodies. This is effected, either by decomposing them into two or more constituent principles, or by forming them from the combination of certain substances. The former process is in chemical language termed Analysis; the latter, Synthesis: and under these are comprehended the greater part of the operations of Chemistry.

Analysis, which, from this definition of it, is merely synonymous with Decomposition, is effected either by the agency of Caloric, or by the exertion of a superior Affinity.

It frequently happens that when a compound is exposed to a high temperature, the force of attraction,

traction existing between its principles is weakened, and they separate; and one of them, being in general more volatile than the other, is expelled.

In other cases, a compound is not decomposed by the most intense heat: but if it be mixed with some other chemical agent, and placed under circumstances favourable to the exertion of chemical attraction, the substance mixed with it may combine with one of its component parts, when of course the compound will be decomposed, and from the products, its constituent principles may be ascertained.

These are cases of Simple Analysis: others more complicated are those, in which two compounds are mixed together, and a complete exchange of their principles takes place; or in which a compound consisting of several principles is exposed to a high temperature, by which its principles are separated, but, instead of passing off pure, they enter into new combinations with each other.

When analysis has been accomplished, the principles which have been separated may frequently

quently be again combined, so as to form the body that was decomposed. This is termed Synthesis, and it is always the surest proof of the accuracy of the Analysis.

As the exertion of Chemical Attraction is much influenced by various causes, -- the temperature of bodies, their state of aggregation, &c.; certain artificial arrangements of circumstances are generally requisite, in order that combinations, or decompositions, may take place. Similar arrangements are necessary to collect the products of these actions. These constitute the Operations of Chemistry.

The circumstance most requisite to the exertion of Chemical Attraction is the minute division of bodies, or the diminution of that force of cohesion, by which the tendency to combination is counteracted. Several preliminary operations are had recourse to with this view, -- as Pulverisation, in which the body is reduced to powder by beating; Trituration, where the same effect is produced by rubbing; and Levigation, where the powder is reduced to a greater fineness by long continued rubbing with a small quantity of water, or any other fluid which is not capable of dissolving

dissolving it. These operations are performed in mortars of metal, marble, earthen ware, or glass. Sifting is the operation by which the finer particles of the powder are separated from the coarser by a sieve: Washing, that in which the same end is attained by diffusing the powder in water, allowing the coarser particles to subside, pouring off the fluid which holds the finer suspended, and allowing these to be deposited. The metals, from their greater hardness, require to be filed down, to be hammered into thin leaves, or to be granulated, by pouring them, when melted, thro' a perforated plate into water.

These operations are very far from reducing bodies to their minute integrant particles, between which only attraction is exerted. They are therefore merely preliminary to those, in which such an extreme division is obtained by chemical means.

Of these, the first is Solution; by which is to be understood, that operation in which a solid body combines with a fluid, in such a manner that the compound retains the fluid form, and is transparent and permanent. Perfect transparency, and the permanent suspension of the solid,

are

are the marks of perfect solution, by which it is distinguished from simple mixture, or mechanical diffusion.

Chemistry is indebted to Newton for the first just view of the nature of this operation. He rejected the vague explanations which supposed it to depend on the figures of the particles, by which the one body was fitted to break down the other; and ascribed it solely to an attraction subsisting between the particles of the two bodies, by which they were united.

In chemical language, the fluid body is termed the Solvent, or Menstruum; the solid, the Solvend. This distinction must not be understood as conveying the idea, that the one body is more active in the operation than the other: the attraction by which it is produced is mutually exerted.

In general, the solution of a solid in a fluid can be carried only to a certain extent; a given quantity of it being dissolved, and no more, though the fluid be kept over it for any length of time. This is termed Saturation, and the fluid in such a case is said to be saturated. The point of saturation in any fluid is very

D

different

different with respect to different solids: of some it will dissolve its own weight; of others, one half or one fourth; and of others, not more perhaps than one or two hundredth parts. With respect to some substances, the solvent power appears to be without limitation. When a fluid is saturated with one substance, it is still capable of dissolving another, but not in such large quantity as it would do were it pure.

An increase of temperature favours solution; it not only facilitates it, or causes it to take place more rapidly, but it enables the fluid to dissolve a larger portion. The larger quantity dissolved is again deposited when the solution cools. The solvent power is not with respect to every body equally promoted by an increase of temperature: Water, for example, will dissolve five, six, or seven times more of some substances, when boiling, than when cold; of others, three or four times; while there are some nearly as soluble in the cold as in the hot fluid. These differences exist principally with respect to those substances termed Salts. Lavoisier has observed that the salts, which have their solubility in water promoted most largely by an augmentation of temperature, are those which are most fusible by Caloric.

Agitation

Agitation favours solution, by removing from the solid the portion of fluid already saturated with it, and bringing a new portion to act upon it. The same end is attained by increasing the surface of the solid body; and hence, in part, the utility of these preliminary operations by which solids are reduced to powder.

By solution we communicate to bodies that fluidity which is necessary for their mutual chemical action, and hence of all the chemical operations it is the most extensive in its application. It is performed in vessels of different kinds, in phials, matrasses or cucurbits of glass. Basons of earthen ware, or metallic vessels are likewise occasionally used.

The second principal operation by which chemical combination between bodies is promoted, is Fusion, or melting them by the application of heat. It weakens the force of cohesion subsisting between their particles, and gives them that fluidity necessary for their motion, and in both these ways facilitates their union. This operation for chemical purposes, and where large quantities are not employed, is performed in vessels termed Crucibles, made of clay with a small proportion of sand,

sand, or of black lead. Sometimes also cups of Iron, Silver, or Platina, are employed.

As an intense heat is often necessary to fuse bodies, as well as for conducting conveniently other chemical operations, Furnaces are very necessary instruments. These are of very various kinds, both in the mode of construction, and in the materials of which they are made. It is sufficient to describe their general structure.

The essential parts of a furnace are the body or fire place, in which the fuel, and the vessel containing the materials to be operated on, are placed; the chimney, by which the smoke and heated air are carried off; and the ash pit, into which the ashes fall, and by apertures in which air is admitted to the burning fuel.

The principles on which the production of heat in furnaces depends, are, that inflammable matter cannot burn without the access of air, and that the rapidity of the combustion, and consequently the quantity of heat produced in a given time, are proportioned to the quantity of air transmitted over the burning matter. When fuel is placed in a closed cavity, like that of a furnace,

nace connected with a chimney, when it is kindled, the air in the upper part of the furnace is necessarily rarified, and ascends by the chimney; the pressure of the external atmosphere forces a quantity of fresh air through the openings below, which, rising through the fuel, occasions a strong combustion.

In furnaces, therefore, the strength of the combustion depends on two circumstances; on the access of the atmospheric air from below, and on the height of the column of heated air. When the tube or chimney is lengthened, the difference between the specific gravity of the column of heated air which it contains, and of the column of external air being greater, a larger quantity of fresh air is constantly forced through the fuel, and a strong draught, as it is termed, is formed. This is proportional to the height of the vent, to a certain extent; for beyond a certain point, the air in the vent being cooled, no addition to the draught is gained.

It is also obvious, that the draught of air may be diminished or increased by lessening or enlarging the access of air from below; and by closing up that access, the combustion will be
totally

totally stopt. Registers, consisting either of a number of holes fitted with brass plugs, or, what is more convenient, of a movable semicircular plate, are employed to regulate the admission of air.

In the construction of furnaces, there is another important object to be attained, the confining the heat, or preventing it from being abstracted by the surrounding air. This is accomplished by coating the internal surface with some substance which transmits the heat very slowly: a lute of clay and sand is commonly used for this purpose, which farther serves the important purpose of defending the substance of which the furnace is made from the action of the fire.

Where a very moderate heat is requisite, the Lamp furnace, or the heat afforded by the combustion of spirit of wine, or oil, by a wick, is very useful. Where the heat is not designed to exceed the temperature of 212° of Fahrenheit, the vessel containing the materials to be operated on is placed in boiling water. This is termed the Water Bath. The Sand Bath is that where sand is used as the medium by which the heat is communicated to the vessel.

The

The Blow Pipe is another convenient instrument for exciting a very strong heat, and operating on small quantities of materials. It is merely a tube with a very small aperture, through which a stream of air is forced, either by the mouth or by bellows, upon the flame of a candle or lamp, and the flame is directed upon a small point where it excites a very intense heat.

An intense heat, the most intense indeed which we can raise, is likewise capable of being excited by the solar rays, concentrated by a concave mirror, or a lens.

There is one other mode in which we can raise the temperature of bodies, so as to facilitate their combination, which is more immediately applicable to the permanently elastic fluids, or airs, that of passing the Electric spark through them. This raises the temperature of the part through which it passes to ignition, at which these bodies combine.

After chemical combination or decomposition has been effected, various operations are requisite in order to obtain the products. Such are Lixivation,

viation, Filtration, Evaporation, Crystallisation, Precipitation, Distillation, and Sublimation.

Lixiviation is merely solution performed with a particular view. If we have a mixture of two kinds of matter, one of which is soluble in water, the other insoluble; by the affusion of a sufficient quantity of water, the former is dissolved, and the latter at length remains pure. This is termed Lixiviation, and the solution a Ley. By Filtration, or passing the fluid through the pores of paper, linen, or other materials, it is separated from the particles which remain suspended in it, undissolved.

Evaporation, understood as a chemical operation, is that in which, by heating a fluid, it is converted into vapour. It is more particularly applied to recover a solid which has been dissolved in any fluid, the fluid being evaporated, and the solid remaining pure. It is performed in vessels of glass, earthen ware or metal, which are of such a figure as to present a wide surface to the air, so that the vapour may escape freely.

When Evaporation is carried on in close vessels, so as to collect the fluid that is volatilized, it forms

forms the process termed Distillation, which is always performed with the view of obtaining the more volatile part.

Distillation is carried on in vessels of different kinds. The common still is made of iron or copper, and the fire is directly applied to the bottom and sides; the vapour passes off by a pipe issuing from the head, and is conducted through a spiral tube, termed a worm, placed in a vessel of cold water, by which its condensation is promoted. The common figure of the still was formerly that of a cylinder, the height of which was at least double the diameter; but it is now made much more shallow, as there can be no doubt that the extent of evaporation is proportional to the extent of surface to which the heat is directly applied, and to the free exit allowed to the vapour.

In the distillation of many substances, metallic vessels would be acted on either by the materials, or the products of the operation. Vessels of glass or of earthen ware are therefore employed; and of these the Retort is the most convenient. It is a kind of conical bottle, the bottom of which is convex, and the neck bent at an angle of about 60 degrees. The materials are

put into the body of the Retort, and heat is applied to it, generally by a sand bath; to the neck, another globular or conical bottle, termed a Receiver, is adapted, in which is condensed the fluid that distils over. Where the product is very volatile, one receiver is insufficient, two or three are therefore inserted into each other. Sometimes this product is permanently elastic, or incapable of condensation by itself. Water, therefore, or some other fluid, must be placed in the receivers, by which it may be absorbed. Woolfe's apparatus is adapted to this purpose. It consists of a series of bottles, connected with each other by bent tubes, one tube always dipping into the water placed in the receiver into which it is inserted. By this contrivance, the permanent vapour is always forced to pass through the fluid. Each bottle likewise has, what is termed, a tube of safety. This is merely a straight tube, immersed about one-tenth of an inch in the fluid in the bottles, by which, whenever a condensation of air takes place in the apparatus, or a partial vacuum is formed, atmospheric air is forced in to supply its place, and prevent the pressure of the atmosphere at the extremity of the apparatus, or that of the air included in the last bottles, from forcing the fluid backward from the one bottle

to the other, by which in many cases the product would be spoiled.

In these and other kinds of apparatus, lutes, or stiff pastes, are necessary to close up the joinings, and prevent the escape of any vapour. They are made of different adhesive materials; as of flour and water, of clay and sand, or of dried clay mixed with drying oil.

Sublimation is an operation similar to Distillation, a volatile body being separated from one more fixed by the application of heat. But the matter thus volatilised, condenses in the solid form, which serves to distinguish the one operation from the other. The apparatus employed for Sublimation is the alembic, with its capital; the former being merely a conical bottle round in the bottom, the other a globular head adapted to it, with a groove or edge in its under part to allow any fluid to run off.

Precipitation is an operation of a different kind. It is applied to that process in which, by chemical action, a solid body is separated from a fluid, and deposited. There are three varieties of it; 1st, That where a solid has been dissolved by
a fluid,

a fluid, and where a third substance, being added, combines with the fluid, and the solid is thrown down : 2d, Where the substance added combines with the solid, and forms with it a substance insoluble in the fluid, and which is therefore precipitated : and, 3d, Where the substance added combines with the body by which the solid had been dissolved, and where both this new compound, and the solid which is separated, are precipitated.

Crystallization is the concretion of a solid, in some regular determinate form, and is of two kinds. When a body has been melted by heat, on allowing it to cool slowly and without agitation, in assuming the solid form, its particles take a regular arrangement, so that its texture exhibits some regular figure. Or if a solid has been dissolved in a fluid, on the removal of part of the fluid by slow evaporation, or on a reduction of temperature, the solid begins to concrete ; and if agitation be avoided, it forms itself into small masses, transparent, and of regular forms. These are termed Crystals ; and the operation itself, Crystallization. Of the former kind of crystallization, the metals furnish examples ; of the latter, the classes of salts and earths. It is the latter kind that is
more

more particularly employed as an operation of Chemistry, to obtain the products of other operations.

Crystallization is promoted by affording a *nucleus*, or solid point, at which it may commence ; and still more so, if this nucleus is of the same kind of matter as that which is dissolved. The access of the air likewise has an important influence on this process. If a saturated solution of a salt in boiling water while it is hot be inclosed in a vessel, so as to exclude the atmospheric air, it does not crystallize even when cold ; but if the air be admitted, the crystallization immediately commences, and proceeds with great rapidity. A production of sensible heat always accompanies crystallization.

Crystals deposited from water always contain a quantity of that fluid, often more than half their weight. It is termed their water of crystallization ; it gives them their transparency and density, these qualities being always lost when this water is evaporated.

Every body that crystallizes takes on a figure peculiar to itself ; and hence the figure of the
crystals

crystals serves as a very obvious property, to distinguish these bodies from each other.

The phenomena of Crystallization have been supposed to be owing to the particles of bodies having a tendency to unite by certain sides in preference to others, probably by those which admit of the most extensive contact; hence, when a fluid in which these particles are suspended is withdrawn, so as to allow of their gradual approach, they will unite by those sides most disposed to union, and thus masses of a regular figure will be formed.

By Crystallization we can frequently separate two substances dissolved in the same fluid. If one is less soluble than the other, after a certain degree of evaporation, it will crystallize, while the latter remains dissolved, and may be obtained by a farther evaporation; or if one is more soluble in hot than in cold water, while the other is nearly equally soluble in each, the one will be obtained by crystallization when the solution is cold; while the other, by the necessary degree of evaporation, will be separated, even while the solution is hot.

CHAP. II.

OF CHEMICAL ATTRACTION, OR AFFINITY.

Attraction, in the language of modern Philosophy, is employed merely as the expression of the general fact, that the masses or particles of matter have a tendency, when left to themselves, to approach until they come into apparent contact. The different species of it have been already noticed and distinguished from each other.

Chemical Attraction, that particular species which we are now to investigate, may be defined, that power by which the particles of heterogeneous bodies have a tendency to unite, and by which, when united, they are retained in a state of combination; forming, not a mere aggregate, or mixture, but a new body, in which the properties of the component parts are more or less changed. Two substances may be intimately mixed together,

ther, and their particles may adhere with considerable force : but however intimate the mixture may be, it still consists of dissimilar parts, separable from each other by mechanical means, and retaining all their properties unimpaired. But when substances are chemically combined, the compound is uniform in its composition, no difference of particles is discoverable, the parts of which it is formed resist every mechanical power of separation, and can be disjoined only by the action of chemical powers. New properties also are acquired different from those of the bodies which have entered into union. By these characters, Combination is distinguished from Mixture.

It is also to be distinguished from Aggregation. This is merely the union of particles of the same kind of matter ; --- the result is an aggregate possessing all the properties of the particles of which it is composed, and existing in different forms, according to the force of attraction by which they are united. In the solid form the force of aggregation is strongest, varying, however, from the extreme of hardness to that degree of softness which yields to a slight pressure ; in the fluid form it is still weaker ; and
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in aeriform fluids it is entirely overcome, and a repulsion established between the particles.

From the difference between Combination and Aggregation, arises a distinction of some importance; that between the integrant parts or particles, and the component or constituent parts of bodies. The latter are particles of matter, differing in their nature from each other, and which, by their union, form a *compound*, or substance, with new properties. The former do not differ from each other; nor do they differ, as to their nature, from the aggregate which they form. They are merely the smallest particles into which a body is divisible without decomposition. They are held together by the attraction of aggregation, or cohesion, while the constituent parts are united by chemical attraction. It is evident that simple bodies consist entirely of integrant parts, all their particles being alike in their properties. Compounds, again, may be considered as consisting both of integrant parts and of component parts, or dissimilar particles. When two compound substances unite chemically, it is the integrant particles which combine, and not the more simple principles of which these are formed.

Such is the nature of chemical combination. What is its cause? In other words, By what power is the union of two different bodies effected? We are indebted to Newton for a satisfactory answer to this question. After having demonstrated the laws of Gravity, and shewn their application to the sensible motions of the universe, he observes, that there might be other species of attraction which reach to such small distances as to have escaped observation. At the end of his treatise on Optics, he reviews a great number of chemical phenomena and actions, and applies this principle to their explanation. When two bodies unite, this he conceives to be owing to an attraction exerted by the particles of the one to the particles of the other, by which they are brought together: when they refuse to unite, it is because no such attraction exists; and when a compound is decomposed by the addition of any other body, it is in consequence of that body exerting an attraction, to one of the principles of the compound, stronger than that which existed between them. These explanations were so much superior to the crude notions formerly entertained by Chemists upon these subjects, that they were generally received. The laws regulating the exertion of chemical attraction have since
been

been investigated by the most celebrated Chemists. As they form the basis of the science, they require to be fully stated.

LAW I. Chemical Attraction is exerted only between the minute particles of bodies.

No exertion of chemical attraction can be perceived between masses of matter. Hence the necessity of mechanical division, in order to facilitate chemical combination. Hence also, when two bodies have united, the smallest parts of the compound are found to consist of the component parts united in their due proportion.

LAW II. The Attraction of Aggregation must be overcome before Combination or Decomposition can take place from the exertion of Chemical Attraction.

This law follows in part from the former; for since attraction is exerted only between the minute particles of bodies, it is evident that, in order to effect a union, the aggregation must be broken, and the bodies to be united reduced to their smallest parts. The circumstance, however,
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destroying the aggregation is not less necessary in another respect; for it is evident, that although we should suppose attraction to be exerted between the particles in the mass, yet a union could not take place, unless the state of aggregation were such as to allow these particles to move to each other in order to coalesce.

From these circumstances arises the necessity of fluidity for chemical combination taking place. When two bodies in the solid state are mixed together, and reduced to the finest powder, they do not act upon each other; but if one or both be rendered fluid, either by solution or fusion, then whatever attraction may exist between them is exerted with effect. Hence has been deduced the chemical axiom, *Corpora non agunt nisi sint soluta.*

To this axiom, that fluidity is indispensable to combination, many exceptions may be stated; there being instances in which, both at low and at high temperatures, solid bodies act chemically on each other. Thus two simple earths, if heated together, will combine, though the temperature be much lower than that which would be necessary for the fusion of either separately.

parately. From the consideration of facts of this kind, Morveau has modified this axiom, and expressed it more justly in the following terms: "There is no chemical action between "bodies, if one of them is not sufficiently fluid," (or rather, if its aggregation is not sufficiently weakened,) "that its particles may yield to "that affinity, which tends to bring them into "contact with the other."

There is another class of exceptions to this law, of a different kind. It is in general true, that the weaker the aggregation is, the more easily combination is effected; liquids, therefore, combine with more facility than solids, or even than a solid and liquid; and in like manner vapours combine with rapidity and ease; so that in many cases, the only practicable method of combining two bodies is, to present them to each other in the state of vapour. There are, however, many other cases in which the state of vapour, especially if it is permanently elastic, opposes chemical union. Few of the Gasses can be combined but at a high temperature, and even then the union is often slow and reluctant. The cause of this circumstance, depending on the agency of Caloric, is afterwards to be explained.

LAW

LAW III. When Chemical Combination has taken place, the compound which is formed does not possess properties merely intermediate between those of its component parts, but has acquired others more or less new.

This law of Chemical Attraction is of vast importance in its application, since it is from it that the properties of the greater number of material bodies are derived. Almost all the productions of nature or of art are compounds of a few simple bodies; and the immense variety of properties they possess, and by which each may be distinguished from every other, is derived from this simple law of attraction, that combination alters, more or less, the properties of the bodies combined. The sensible qualities, such as taste, smell, colour, form and density; and the chemical properties of fusibility, volatility, solubility, tendency to combination, and order of attraction in the compound, bear in general no resemblance to the same qualities in its constituent principles. In no case, therefore, can we, from our knowledge of two bodies, infer with certainty, *a priori*, what will be the properties of the compound which results from their union.

It

It is not invariably true, however, that the properties of a body are completely changed by its combination with another. There are many examples in which they are only slightly altered or weakened; and there are some, the solutions of salts in water for example, in which they are scarcely perceptibly changed; though that these are real chemical combinations is certain, as they are not destructible but by the exertion of a superior affinity. In these and in other cases in which the properties of a body are little altered, there is generally one change which marks chemical union, an alteration of specific gravity, that of the compound not being the mean of the specific gravities of the component parts.

LAW IV. The exertion of Chemical Attraction is accompanied by a change of temperature.

This law, if not universal, is at least very general; there being few instances of chemical action which, if accurately observed, do not shew a change of temperature, and in many cases a very considerable one. The temperature may be either increased or diminished; in other words, either heat or cold may be produced:
and

and the great source of both these changes, especially in the operations of art, is chemical combination. The cause of this change, belonging to the consideration of Caloric, will be afterwards explained.

LAW V. In the greater number of bodies, there are certain limits to their combinations with others; in other words, there are certain proportions in which they combine with each other.

This law comprehends several varieties of combination.

1. There are many bodies which will combine together in only one proportion; and if an excess of either ingredient of the compound be added, it will either be merely mixed with it, or collected apart from it, with its properties unchanged. Hydrogen and Oxygen in their union, afford an example of this kind.

2. There are other cases in which two bodies will combine together in two proportions, in three, or even in four; each of these combinations producing a compound distinguished from the
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the other by peculiar properties. Thus oxygen unites with azot, in not less than four proportions, each proportion forming a different compound. This peculiarity of combination is highly important; the immense variety of properties, in the products of the vegetable and animal kingdoms, being chiefly derived from slight differences in the proportions of the few principles of which they are formed.

3. In certain circumstances, the combination is unlimited to a certain extent: one body may combine with another in any proportion, until a certain quantity of it is combined; but beyond that quantity, the capability of combination ceases. The solutions of salts in water afford examples of this kind. Any portion of salt, to a certain quantity, combines with the water; but more than that quantity cannot be dissolved.

Lastly, there are cases of combination apparently unlimited, two bodies uniting in every possible proportion. Alcohol and water, or sulphuric acid and water, afford examples of this kind: they unite in whatever proportion they may be mixed together, and the compound has always a specific
G gravity,

gravity, different from the mean specific gravity of the fluids combined.

Of some of these classes of facts, Guyton (late Morveau) has given a different statement, which seems to be generally admitted. He supposes, that any two bodies are capable of combining only in one precise proportion; but the compound which is thus formed may farther combine with a new quantity of one of its constituent parts, and this may be carried to the length of two, three, or four successive combinations. All the compounds, therefore, which were formerly considered as combinations of bodies in different proportions, are supposed to be successive combinations of the compound formed, with new quantities of one of its ingredients.

This opinion applies with facility to those cases of combination in which bodies unite in two, three, or perhaps four combinations; and with respect to many of these, it is probably just. But in those cases where combination is unlimited, as in the union of acids, or of alkohol with water, it is impossible to conceive how the combinations can succeed each other, in the manner which Morveau has supposed.

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The limitation of combination, which has been noticed under this law, forms what is termed, in the language of Chemistry, Saturation. When one body has combined with another in the largest possible proportion, it is said to be saturated; and the precise proportion in which they have thus combined, is termed the point of Saturation.

LAW VI. Attraction is in the inverse ratio of Saturation: Or those particles which enter first into combination, so as to form a peculiar combination, are united by a stronger attraction than those which are afterwards added.

This law has been inferred from the facts stated under the preceding; and it is in general just. Among those bodies which unite in two or three determinate proportions, there is scarcely one exception to it; the force of attraction being strongest in the first compound, and weaker in the others. Hence there are many of those compounds which it is possible to decompose partially, even by the interference of very weak attractions, while it is extremely difficult to effect their entire decomposition.

LAW VII.

LAW VII. Chemical Attraction may be exerted at the same time between more than two bodies, so as to bring them into combination.

Nature presents us with a great number of compounds, especially in the animal and vegetable kingdoms, consisting of three, four, or even more simple substances; and art can also effect combinations in which there are three or four elementary substances united. In such cases, it is conceived that the attractions are mutually balanced; and it is observed, that such combinations generally take place between those bodies in which the different attractions are nearly of the same force. Compounds of this kind are termed, Ternary, Quaternary, &c. according to the number of their principles.

On this subject, Morveau has advanced an opinion similar to that which he entertains respecting the union of bodies in different proportions. He conceives, that when several bodies are mixed together, and one apparently homogeneous compound is produced, they do not all directly combine; but two of them first unite, and the compound they form combines with the third; as this new compound may again

gain combine with a fourth, if it be present. In confirmation of this opinion, it is observed, that very frequently if two of the bodies be first combined, and then the third be added, the same compound is produced as when they are all directly mixed. This, however, is by no means always the case; and there are even some facts, particularly the solutions of two or three substances in the same fluid, of different salts in water for example, which are unfavourable to this opinion.

Under this law may be noticed what has been termed by Chemists, the Affinity of Intermedium. There are many instances in which two bodies do not combine together, but on the addition of a third substance, a chemical union is effected. Such cases, however, are merely examples of a compound being formed of two substances, and this combining with a third body.

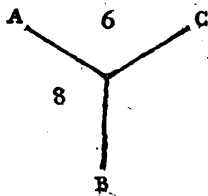
LAW VIII. Bodies exerting an Attraction to others, exert it with different degrees of force, each individual having its peculiar attraction to others, which can be only ascertained by observation or experiment.

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This is the most important law of Chemical Attraction, since it is the source of by far the greater part of the combinations of chemistry.

From the attraction exerted by one substance to another, their combination takes place; and all bodies between which such an attraction exists, may be made to unite. But in consequence of this law, that the attractions exerted by any body towards others are different in their force with respect to each, we are able, when two have combined, to decompose the compound they have formed, by adding, under the circumstances necessary for the exertion of chemical attraction, any body which has an attraction to one of them superior to the attraction by which they were held united. The two bodies between which there is the strongest attraction combine, and the third is separated.

This may be illustrated by a diagram.



Suppose A to have an attraction to C, equal in force to 6. If placed under the necessary circumstances of division and temperature, they will unite and form a compound A C. But suppose A to have an attraction to B equal to 8, if B be added to the compound A C, it will immediately decompose it by uniting to A. The compound A B will therefore be formed, and C will be disengaged. The same decomposition, it is evident, would have been produced, if the attraction between B C had been superior to that between A C. B would have combined with C, and A would have been separated.

The same principle may be illustrated by experiment, by substituting Nitric Acid for the letter A in the above diagram, Potash for B, and Lime for C.

After the fact was discovered that the force of attractions was different, it was a very obvious idea to construct tables in which the relative forces of attraction of any substance towards others might be exhibited, so far as these were ascertained by experiment. This was first done by Geoffroy, a French Chemist. These have been extended,

extended, so as to comprehend a great part of the combinations and decompositions in Chemistry. They are merely columns, at the head of which is placed the name of the substance whose attractions are to be enumerated, and the different substances for which it has an attraction are placed beneath it, in the order of their forces of attraction, as in the following example.

L I M E.	N I T R I C A C I D.
Oxalic Acid	Barytes
Sulphuric Acid	Potash
Tartarous Acid	Soda
Phosphoric Acid	Lime
Nitric Acid	Ammonia
Muriatic Acid.	Magnesia.

There remains to be explained another case of elective attraction, more complicated.

Suppose we have a compound formed by the union of A and B, in which the force of attraction is equal to 20, and that to this compound another substance, C, be added, which has an attraction to A, equal to 16; it is evident that no decomposition can ensue. But suppose D, a
fourth

fourth substance, is united to C, with an attraction equal to 7; and suppose that D has an attraction to B equal to 12, then a decomposition must be effected on mixing these two compounds; for the sum of their existing attractions is inferior to the sum of those tending to separate them, the one being 27, the other 28. A B, C D, therefore are decomposed, and two new compounds, C A, B D, are formed.

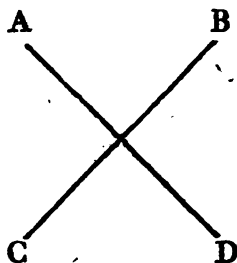
This is what is termed, in the language of Chemistry, Double Elective Attraction; two elective attractions being exerted, and two new compounds formed. Of the two attractions which are exerted, one tends to preserve the original compounds undecomposed; the other tends to separate their principles. The former have been termed by Mr Kirwan the Quiescent, the latter the Divellent Attractions, terms which are generally used. It is evident that a double decomposition can only be effected, where the sum of the divellent is superior to that of the quiescent attractions.

In order to represent more clearly and concisely what passes in these complicated attractions, diagrams have been constructed. The i-

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dea seems first to have occurred to Dr Cullen. The one he proposed was that of two cylinders crossing each other at the middle.



If on mixing the compounds denoted by AC , BD , the attractions of A to B , and of C to D , overcome the quiescent attractions, AC , BD ; the resulting decomposition is represented, by supposing the extremities AB , CD , of the cylinders to be brought together; by which also the production of the two new compounds will be denoted by the conjunction of these letters.

The diagram proposed by Bergman, consists of two brackets connected by straight lines, forming a square, at the sides and corners of which the names of the existing compounds, and of their ingredients, are placed.

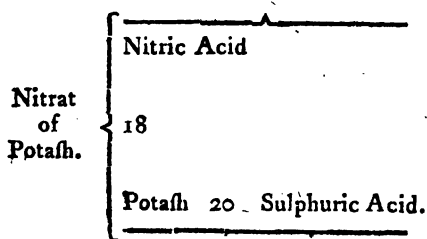
Muriat,

Muriat of Potash.			
Potash		32	Muriatic Acid
Sulphat of Potash	62	▽	20=82
	Muriat of Lime,		
Sulphuric Acid		54 86	Lime
Sulphat of Lime.			

Thus in the scheme which Bergman himself gives, if the two compounds, termed Sulphat of Potash and Muriat of Lime, the former consisting of Sulphuric acid and Potash, the latter of Muriatic acid and Lime, be mixed together, a double decomposition takes place, and two new compounds, Muriat of Potash, and Sulphat of Lime, are formed. This is represented by placing on the outer sides of the two brackets the names of the two compounds mixed, and at the corners of the brackets, the names of their ingredients, so disposed that the one acid shall be diagonally opposite to the other. If the numbers expressing the relative force of attractions of the principles of those compounds be also added, it will

will be obvious that a decomposition will ensue. If the attraction between Potash and Sulphuric acid be 62, and that between Lime and Muriatic acid, 20, the sum of the quiescent attractions will be 82. But if the attraction between Potash and Muriatic acid be 32, and that between Sulphuric acid and Lime 54, the sum of the divellent attractions will be 86. These, therefore, will operate with effect; the Muriatic acid and Potash will combine together, as will the Sulphuric acid and the Lime, and the names of these resulting compounds, Muriat of Potash and Sulphat of Lime, are placed without the straight lines, by which the brackets are connected.

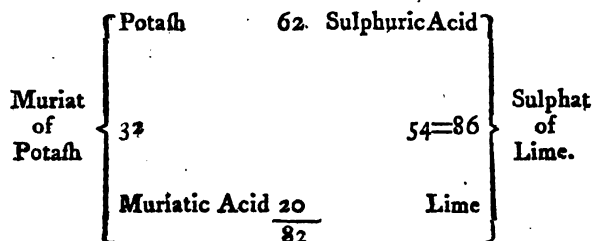
To represent a single elective attraction, the same figure is used, with only one bracket, as in diagram 4.



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By some slight variations in their construction, these diagrams have been rendered still more extensive, so that they are capable of representing all the phenomena of these combinations.

Where the quiescent attractions are superior to the divellent, and where of course no decomposition takes place, the scheme consists of two unconnected brackets, with the names of the compounds at each side, and of their ingredients at each corner; the numbers, denoting the forces of attraction, being interposed.



In the opposite case where decomposition is effected, the scheme No. 3 is used, varied only to shew the peculiar phenomena,

Thus in such decompositions it frequently happens, that one or both of the new compounds
prove

prove insoluble, and consequently fall down. This is denoted by bending downwards, in the middle, the line placed between the substance and the square, as in diagram 3, where the undermost line is bent down to express that the Sulphat of Lime is precipitated. If, on the contrary, one of the substances be volatilised or sublimed, the line is bent upwards in the middle, as in diagram 4, where the upper line is drawn in this manner, to shew that the Nitric acid is volatilised. If they are neither precipitated nor volatilised, the brackets are merely connected by two straight lines.

Lastly, the circumstances under which the decomposition takes place, require to be pointed out. Sometimes it is effected, by the substances being dissolved by water, sometimes by the application of heat to them in the solid state. Bergman distinguished these decompositions in the humid and in the dry way, by inserting in the middle of the diagram a triangle, Δ , which was the old chemical mark for fire, to denote that the decomposition was effected in the dry way, or by the application of heat; and an inverted triangle, ∇ , the mark for water, to point out when it was done in a watery solution. The same method is still used

used, the marks only being changed; a straight perpendicular line, |, is the mark for caloric, or heat; a compound figure, H , for water.

To facilitate the construction of such diagrams, all the chemical agents have likewise been distinguished by particular characters.

There is a peculiar case of chemical decomposition, formerly regarded as anomalous, which may be noticed under this law. It is what has been termed Reciprocal Attraction. It is that case in which a compound is decomposed by the addition of a third body, and yet the principle disengaged is capable of reacting upon the compound, so as to decompose it again, and form a quantity of the original substance. An example will illustrate it. If Sulphuric acid is poured on the compound termed Nitrat of Potash, it decomposes it by combining with one of its principles, the Potash, and disengaging the other, the Nitric acid: but if this Nitric acid be again digested on the compound of Sulphuric acid and Potash, it decomposes it, and a quantity of Nitrat of Potash is found to be formed. Still there can be no doubt that the attraction of Sulphuric acid, is much stronger than that of Nitric acid to Potash

Potash. How therefore is the latter decomposition produced?

Bergman, by an admirable explanation, has removed this apparent exception to the uniformity of the laws of chemical attraction. He observes, that Potash can combine with Sulphuric acid in two proportions, one in which they are mutually saturated, and a perfect neutral salt is formed, another in which the acid is in excess, and which may therefore be considered as a compound of the neutral salt with a fresh quantity of Sulphuric acid. When the Nitric acid is added to the Sulphat of Potash, there are two conspiring affinities; the one that of the Nitric acid for Potash, the other that of the Sulphat of Potash for an excess of Sulphuric acid; and these being superior to the bare quiescent attraction between the Sulphuric acid and the Potash, the decomposition is effected. The proof that this explanation is just, is, that whatever quantity of Nitric acid be added, not more than a certain quantity of the Sulphat of Potash, about one third, can be decomposed: because when the two thirds of the neutral salt acquires the fresh quantity of the Sulphuric acid, there remains only the simple attraction of the Potash to the
Nitric

Nitric acid, which is unable to effect the decomposition. Another decisive proof of its justness is, that the Nitric acid has no effect on the same compound of Potash, with an excess of Sulphuric acid.

What is termed *Disposing Affinity*, or *Attraction*, furnishes another apparent exception to the uniformity of force with which chemical attraction operates. It is that case in which two bodies are incapable of uniting, but in which the combination is effected by the addition of a third body, though it has no apparent attraction to either of the others, or at least none which, by any obvious operation, can facilitate the union.

This will be better illustrated by example. Water is a compound of oxygen and hydrogen; phosphorus has an attraction to oxygen, but not sufficiently strong to enable it to decompose the water: but if the phosphorus be combined with lime, it decomposes water rapidly, by attracting its oxygen. Iron, in like manner, has an attraction to oxygen; but so little superior to that of hydrogen, that it is unable to decompose water at a low temperature, or at least the decomposition is very slow: but if a small quantity of sulphuric acid

be added, it immediately commences with great rapidity. In the one case the Lime, in the other the Sulphuric acid, is said to exert a disposing affinity. The explanations that have been offered of the nature of this operation, are unsatisfactory, some of them absurd. The term, however, of Disposing Attraction may be retained, as the expression of the general fact, which is unquestionable, that chemical union between two bodies is often facilitated by the addition of a third, which exerts no apparent attraction to either that can influence the result. When the nature of this action is discovered, it will be expressed with more precision as a particular law, or it will be reducible to some of the other established laws of attraction.

LAW IX. The force of attraction between bodies is not estimated by the facility with which they combine.

Though it might be supposed, that these bodies, between which the strongest attraction exists, would combine most easily, yet we find this is not the case. Some combine with facility, which have comparatively a weak attraction to each other; while others, between which a strong attraction exists, are combined with difficulty.

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This is owing to the exertion of chemical attraction being always influenced by the state of aggregation, the disposition to fusibility or volatility, and other circumstances.

The problem of determining the relative forces of chemical attraction amongst different bodies, is highly important; but hitherto we have only approximations to its solution. The usual measure of the force of attraction is, that of decomposing a compound by the addition of a third body. But all that we learn from this is, that the attraction of one is stronger than that of another to a third: how much stronger it may be, or what is its absolute force, is not determined.

Morveau observed, that different metals, placed in contact with mercury, adhere to it with different degrees of force, which he found to be in the order of the different chemical attractions of these metals to mercury. This method, therefore, might be followed, as a mean of determining the relative forces of attraction; but it is so limited in its application, that it cannot be applied to the solution of the general problem.

Mr Kirwan, in making experiments on the
saturation

saturation of the acids by the alkalis and earths, discovered, that the quantity requisite to saturate an acid, is directly as the force of attraction subsisting between the acid and base; 100 grains, for example, of Sulphuric acid, require for saturation 215 grains of Potash, 165 of Soda, and 110 of Lime: as it is known that Potash has a stronger attraction to that acid than Soda, and Soda than Lime, Mr Kirwan concluded, that the above numbers express the proportional forces of attraction in these bodies. But it has been found, that on mixing different compound salts together, the actual results are not always such as ought to be obtained, did the above numbers express the precise forces of attraction of these substances; and Mr Kirwan himself has pointed out sources of fallacy in the original experiments, against which it is scarcely possible to guard.

LAW X. The exertion of chemical attraction between bodies is influenced by their state with respect to temperature, independent of any effect that temperature may have in changing their forms.

It has already been observed, that fluidity is in general a necessary requisite for the exertion of chemical

chemical attraction, and that fusion, by the application of heat, is one method by which this fluidity is obtained. But besides this, there are many cases in which it is necessary to expose bodies to a high temperature, in order to bring them to act chemically on each other; altho' the heat applied is not carried so far as to render either of them fluid. It is this circumstance that is comprehended under the present law.

This influence of temperature may be noticed, first, as it promotes Combination. Of this there are two cases; that in which the force of chemical attraction seems to be augmented, and that in which its exertion appears to be only facilitated, by a high temperature.

Of the first of these, the solutions of the salts in water afford examples; a larger quantity of the salt combining with a given quantity of water, at a high than at a low temperature, and this larger quantity being deposited when the temperature is reduced. The power of combination is therefore, in this case, *augmented* by the increase of temperature.

Of the second case, that in which the exertion is only *facilitated* by the agency of Caloric, or in which bodies require to have their temperature raised to a certain point, in order to combine, but the combination remains unaltered by any reduction of temperature, there are many examples.

Thus several of the pure earths, when mixed together and exposed to a high temperature, unite, though the temperature be still inferior to that necessary to melt either of them previous to their combination; these earths are likewise insoluble in several of the acids, unless the acid be boiled upon them; and the greater number of inflammable substances are incapable of combining with oxygen gas, but at a high temperature.

In all these cases, it is evident that Caloric may promote combination, by diminishing the force of aggregation by which the particles are held together, and by which chemical attraction is counteracted. The whole of the effect cannot, however, be ascribed to this cause; for there are cases in which bodies combine with others at low temperatures, though in neither of them is the power of cohesion remarkably weak, or chemical

cal attraction proportionally strong ; while others require to be exposed to a high temperature in order to combine, though the chemical attraction which they exert to each other is powerful, and their aggregation not greater than it is in those which combine with more facility. The comparative relations of Phosphorus and Charcoal to Oxygen, or of Copper and Arsenic to the same principle, afford examples of this kind.

The influence of temperature is equally extensive with respect to decomposition. Many substances remain in union within a considerable range of temperature ; but if the temperature be raised beyond a certain point, the attraction between them is overcome, and, of course, the compound which they form is decomposed.

In such cases of simple decomposition, it is perhaps always true, that one of the bodies is volatile, or easily convertible into vapour, while the other is comparatively fixed : hence the application of Caloric will act with unequal force on the component particles of the compound ; it will have a much greater effect on those of the volatile body, than on those of the fixed ; they will be separated from each other ; and the separation

ration proceeding till they are placed without the sphere of mutual attraction, decomposition is produced.

There are other cases of a similar nature in which the attraction of a third body is introduced. The compound cannot be decomposed merely by raising its temperature to any point: but if it be mixed with some other substance which has an attraction to one of its component parts, especially to that which is fixed, this attraction, co-operating with the expansive force of the Caloric, effects the decomposition.

Lastly, a double elective attraction, which cannot otherwise be accomplished, is often effected by exposing the substances to a strong heat. In such cases, though part of the effect is also to be ascribed to the Caloric diminishing the force of aggregation, it is not entirely owing to that cause; since frequently the same effect is not produced when the aggregation is diminished by solution in water; on the contrary, affinities of an opposite kind are frequently exerted.

There are also cases of double decomposition, which are effected only at a very low temperature;

perature; but these are evidently of a similar kind.

From these facts it is obvious, that Caloric powerfully modifies the exertion of chemical attraction. So far as its effects are referable to its power of lessening aggregation, they are easily understood; but we find this cause insufficient for the explanation of every case, in which its modifying power is present; nor has the theory of its effects been fully elucidated. Some have attempted to solve the difficulty, by supposing Caloric itself to exert, in such cases, a chemical attraction: but this involves an inadmissible hypothesis, and at any rate it cannot be applied with sufficient precision.

It only remains to state the opinions entertained respecting the nature of chemical attraction.

Since the laws of its action are different from those which regulate the actions of the other kinds of attraction, the obvious conclusion is, that it is to be regarded as a peculiar power. Some philosophers, however, from a fondness for generalization, have endeavoured to shew, that the attractions exerted between the minute particles

of bodies, whether homogeneous or heterogeneous, are only modifications of that more general power exerted between the masses of matter, and at the greatest distances; in other words, that the attractions of aggregation and of combination are ultimately the same with the attraction of gravitation.

The circumstance that has been particularly pointed out as modifying these attractions, is that of the figures of the particles of bodies. "Considering the vast distance, we may neglect the diameters, and look upon the heavenly bodies, in most cases, as gravitating points. But contiguous bodies are to be regarded in a very different light; for the figure and situation, not of the whole only, but of the parts, produce a great variation in the effects of attraction. Hence, quantities, which in distant attractions might be neglected, modify the laws of contiguous attraction in a considerable degree."†

This question is one which it is scarcely possible to determine with certainty, since we have it

† Bergman.

it not in our power to estimate the force of those modifying circumstances which no doubt in part exist; and it is one comparatively of inferior importance, since the laws by which these attractions act must still be determined from observation and experiment.

CHAP.

CHAP. III.

OF CALORIC.

THE terms heat and cold, as denoting certain sensations, though incapable of strict definition, are sufficiently well understood. These sensations are excited by bodies applied to the organs of animals ; and as the same body, at different times, excites very different sensations, its power of exciting them is considered as depending on a certain quality it possesses, or a peculiar subtle principle present in it ; and which, according to its intensity or quantity, will give rise to these different effects. If the body applied contain a certain quantity of it, the sensation of heat is excited ; if the quantity be diminished to a certain extent, that of cold is produced ; and the intensity of either sensation is proportioned to the accumulation or diminution of this quality or principle.

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This power, whatever be its nature, is capable of being communicated to all bodies. When present in one, it may be transferred from it to another; and then the power of exciting the peculiar sensation is also transferred: and this communication may continue to be made, till a perfect equilibrium of power is established.

Philosophers have further observed other peculiar effects which it produces. When a body is heated, it is also invariably expanded, or its volume is augmented in every direction; when it is cooled again, the volume is diminished; and the diminution or increase of volume is always proportioned to the abstraction or addition of the peculiar power on which these effects depend.

It has, lastly, been proved, that when this expansion is carried to a certain extent, bodies change their forms, solids becoming fluids, and fluids being converted into vapours or airs.

These effects being thus inseparably connected, are justly considered as arising from the exertion of the same power. It has been distinguished by different appellations; as Fire, Heat, the Matter of Heat, or the Igneous fluid,---terms now superseded

superfeded by the more unexceptionable appellation of Caloric.

By Caloric, then, is to be understood, a power or quality present in bodies, the cause of their expansion, and of their conversion into the fluid and aeriform states ; and which, when present in a certain quantity, excites in animals the sensation of heat ; the sensation of cold being also the effect of its abstraction.

Some have considered this power, as a peculiar subtle fluid diffused over matter, and capable of entering into every body : others have supposed all the phenomena exhibited by heated bodies to arise merely from a peculiar state of those bodies, or, to speak more precisely, from a vibratory motion, more or less violent, of their minute particles. The question on this subject will be more properly discussed after the effects of Caloric have been considered. It is sufficient to remark, that whatever may be the nature of this power, its existence as the cause of certain effects is demonstrated ; and these effects, their relations to each other, and the general laws according to which they are produced, may be investigated with

with sufficient precision, though the nature of the cause may remain unknown.

EFFECTS OF CALORIC.

THE state of a body, with respect to its power of producing the effects above enumerated, as arising from the presence of Caloric, is termed Temperature. In each body, the temperature depends on the quantity of Caloric it contains. If at any temperature it contain a certain quantity, the addition of more Caloric raises the temperature, or the body now possesses the power of exciting either a weaker sensation of cold, or a stronger sensation of heat, and of producing in other bodies a greater degree of expansion. An abstraction of Caloric equally causes a reduction of temperature.

Formerly the temperature of a body was estimated by the sensation which it excites; but the sensations of heat or cold, like all others, are so much influenced by external circumstances, independent of the direct cause by which they are excited, that no dependence can be placed in
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the apparent result: and even if the sensation did afford us accurate information, it could do so for only a very small part of the range of temperature; since, beyond a certain point of intensity, either of heat or cold, it admits of no discrimination.

The mode, therefore, of estimating the temperature of bodies, by the expansion they suffer from the introduction of Caloric, or the invention of the Thermometer, was an important acquisition. The honour of it is due to Sanctorius, an Italian physician. He had observed the great expansion which air undergoes when heated; and it occurred to him, that this expansion might be used as a measure of the variations of temperature, by confining the air in a vessel, with a small quantity of fluid, which, by its ascent or descent, as it was pressed upon by the expanded or contracted air, might shew the minute alterations of volume. This accordingly formed his air thermometer, which, for distinguishing very minute variations of temperature, is still sometimes employed.

An important improvement was made in the instrument, by substituting a fluid as the measure
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of expansion, instead of air, and confining it in a tube hermetically sealed. Alkohol and Mercury are the fluids now always employed: the former for measuring low temperatures at which mercury would freeze; the other, as being more equable in its expansions, is preferred for measuring the variations of every other temperature to which it can be applied.

The *thermometer*, constructed with either of these fluids, consists merely of a glass ball, which terminates in a long cylindrical tube, of a very small bore, and partly filled with the thermometrical fluid. According as Caloric is communicated to the fluid in the ball of the thermometer, or abstracted from it, its volume increases or diminishes, and it therefore rises or falls in the tube. The changes of volume are accurately measured by a graduated scale: and thus the temperature of any body in contact with the ball is ascertained.

In order that different thermometers may correspond together, it is necessary that two fixed points may be established, between which the scale may be divided, so as to render it always uniform. These points ~~have been~~ obtained in

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the freezing and boiling of water. Water freezes always at one precise temperature : if therefore the thermometer be immersed in water which is freezing, or, what is the same, in melting snow or ice, the thermometrical fluid will descend to a certain part of the tube, where it will stop ; and if this be marked, we obtain one fixed point, which must be the same in every thermometer. Water boils likewise under the medium pressure of the atmosphere always at one uniform temperature : if the thermometer, therefore, be immersed in water boiling under this pressure, the mercury will rise, and stand at a certain part, which being marked, will afford us another invariable point ; and if these two points be connected by a scale, divided into any number of degrees, every intermediate temperature may be ascertained with accuracy. In different countries, the division of the scale has been different ; but when two points are thus fixed, it is easy, by calculation, to bring them to correspond with each other. In every thermometer, the scale divided in a similar manner is extended from both these points, descending from the one, and ascending from the other.

Fahrenheit's and Reaumur's are the thermometers that have been generally used. In the former,

former, which is the one used in this country, the scale commences at the temperature produced by a mixture of snow and sea salt; this being the lowest temperature known in Fahrenheit's time. The range of temperature between this and the freezing point of water, is divided into 32 degrees; that point, therefore, stands at the 32d degree. That part of the scale between the freezing and boiling point of water, is divided into 180 degrees. The latter point is therefore equal to 212.

The division of Reaumur's, which has been generally used in France, is more simple. The freezing point of water is termed the Zero, or 0; and between that and the boiling point of water, there is a scale divided into 80 degrees, the point at which water boils being termed the 80th degree above 0. To express higher temperatures, the scale is carried on, divided into degrees equal to those inferior; and in like manner to denote diminutions of temperature below the freezing point: a descending scale, divided into equal parts, commences at that point.

The correspondence between observations made with these thermometers is easily discovered.

vered. Each degree of Fahrenheit's scale is equal to $\frac{4}{9}$ ths of a degree of Reaumur's. If, therefore, the number of degrees of Fahrenheit, reckoned above or below the freezing point, be multiplied by 4, and divided by 9, the quotient will be the corresponding number on the scale of Reaumur.

The centigrade thermometer, the use of which has been lately established in France, has a scale in which the range of temperature between the freezing and boiling points of water is divided into 100 degrees.

In order that the thermometer might be employed with certainty as an instrument for measuring variations of temperature, it was necessary to ascertain that the expansion and contraction of the thermometrical fluid corresponded in every degree to the addition or abstraction of caloric. Experiments have been made with great great care to determine this point, and it has been found that in several fluids, as water, spirit and oil, the expansions do not exactly correspond to the increments of temperature. Mercury likewise suffers some irregularities when its temperature rises nearly to its boiling point. But at
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all natural temperatures it is found to be sufficiently exact; and it is therefore the fluid of all others the most proper for the construction of the thermometer. Alcohol, however, must be used for measuring very low temperatures at which mercury would freeze,

To measure very high temperatures, different methods have been proposed. The one that is generally used is that founded on the particular property of clay, that it contracts instead of expanding by heat. This forms the thermometer, or pyrometer, of Wedgwood. It consists of two pieces of brass, fixed on a plate, so as to be $\frac{6}{10}$ ths of an inch asunder at one end, and $\frac{3}{10}$ ths at the other: a scale is marked upon them, and small pieces of baked clay are adapted to this gage, so as merely to enter it. The higher the temperature to which one of these pieces of clay has been exposed, the greater is the contraction in its volume, and of course the farther does it enter the gage. High temperatures can thus be ascertained with tolerable accuracy. Each degree of this thermometer is equal to 130° of Fahrenheit's.

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Since the employment of the thermometer, or rather of the expansion of bodies as a measure of their temperature, more just and enlarged views have been acquired of the distribution of caloric. While the property of exciting the sensation of heat was the only one by which that power was characterised, it seemed an obvious and just conclusion, that those bodies which did not excite that sensation contained no caloric or heat; and this was then the philosophical, as it is still, perhaps, the popular opinion.

Its fallacy, however, is easily pointed out. That the sensation which bodies excite is no just indication of the quantity of caloric they contain, may be easily shewn, by stating the manner in which these sensations are excited.

The temperature of the human body is generally about 96° of Fahrenheit. When any substance at a higher temperature than this is applied to our organs, it gives out caloric to the part to which it is applied, and this excites the sensation of heat; when, on the contrary, it is of a lower temperature, it abstracts caloric, and this gives rise to the sensation of cold. Our sensations, however, are all of them much influenced
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by preceding impressions. Our body is surrounded with an air, at a temperature at least in this climate always inferior to the animal temperature; it is therefore always abstracting caloric. Hence it happens that if any matter is applied to the body inferior to its temperature, but superior to the temperature of the surrounding atmosphere, the abstraction of caloric which it produces is inconsiderable; and, compared with the impression which the air makes upon us, seems hot,—in other words, less cold.

In general, therefore, it may be affirmed, that whatever communicates caloric to our body produces the sensation of heat, and that whatever abstracts it causes the sensation of cold; but that abstraction requires at least to be greater than that made by the surrounding atmosphere, in order to convey to us the sensation of positive cold.

It is to be observed too, that different bodies at the same temperature will occasion different sensations, according to the rapidity with which they absorb, or give out caloric. A piece of iron at 32 will feel much colder than a piece of wood at that temperature; because the former abstracts
caloric

caloric from the hand, or whatever part of the body touches it, much more rapidly than the other.

From these circumstances, it is evident, that the sensation excited by a body is no accurate measure of the caloric it contains, and that the sensation of cold will be excited by any substance whose temperature is inferior to that of the animal body, though that substance may, and actually does contain a large quantity of caloric.

That bodies at such a low temperature contain it, is evident from the fact that their temperatures can be still farther reduced. If the thermometer be immersed in water which is freezing, the mercury will stand at 32° on Fahrenheit's scale; but even in the cold of this climate, it falls occasionally much lower. At 32° , therefore, the mercury must have contained caloric, since it is only by the abstraction of this power that it could contract in volume, and of course descend in the scale. At Hudson's Bay the mercury has descended to 46 degrees below 0 of Fahrenheit, or 78 below the freezing point of water, and in Siberia to a still lower point. At all degrees, therefore, above this, the thermometer must have contained caloric; and even at that intense cold, of which
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it is difficult to form a just conception, it must have contained much caloric, since, by artificial means, a still further reduction of it could be effected : and if the mercury in the thermometer contained caloric in these extreme colds, all bodies must have contained it, since it is the invariable property of this power to diffuse itself, till an equilibrium of temperature is established.

But even at that temperature, there is not the least reason to believe, that bodies were near to being deprived of their caloric, since even then their particles must have been far from being in actual contact ; and it is only by the repulsive power of caloric that these particles are kept asunder. This affords a still more extensive view of the distribution of this power. A solid body is to be conceived of as consisting of a number of particles of the same nature, kept at certain distances from each other by its agency or interposition : when a portion of caloric is withdrawn, these particles approach nearer to each other ; and hence the diminution of volume that takes place. But any condensation hitherto effected, is very far from that in which these particles would be in contact ; nor, perhaps, is such a condensation possible.

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It has farther been established, that the fluid and aeriform states of bodies are owing to the presence of caloric: and therefore, as many fluids require to be exposed to the most intense cold in order to freeze them, as there are even some which have not yet been frozen; and further, as the greater number of the airs have not yet been brought even to the fluid state,—it is evident that the lowest temperature which has been produced, is far from that point at which caloric would be totally abstracted.

We are therefore “ to consider all bodies on
“ the earth, and this planet itself, as penetrated
“ with an immense quantity of caloric, of which
“ it is impossible for us to deprive them entirely,
“ to whatever degree we may diminish their
“ temperature.” ‡

It is a portion of this caloric that is so frequently disengaged, and rendered sensible, by chemical action, as in the familiar example of combustion.

OF

‡ La Place.

OF EXPANSION.

OF the effects produced upon bodies by Caloric, the most general is Expansion. When the temperature of a body is raised, its volume is augmented in every direction; and when the temperature is again reduced, it contracts, and continues contracting, proportional in general to the reduction of temperature.

In different bodies, the expansion produced by the addition of a given quantity of caloric is very different; solids are much less expanded than fluids, and fluids much less than vapours or airs: and in general it may be said, that the expansibility is inversely as the density. It is only in a general sense, however, that this is true; the exceptions to it are even numerous: metals, for example, are more expanded than glass, by a given change of temperature, though they are much more dense.

Neither are the expansions in each body proportioned to the quantities of caloric it receives. If a certain degree of expansion be produced by
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the communication of a given quantity of caloric, that produced by a quantity double of the former will not be precisely double. In general it has been found that the expansions go on in an increasing series; they suffer a greater degree of expansion at a high temperature, than they would do from the addition of an equal quantity of caloric at a lower temperature. Mercury is more regular in its expansions than any other substance that has been examined.

To the law that bodies are expanded by caloric, there are some remarkable exceptions. The freezing of fluids, or their transition to the solid state, is the most general one. When a fluid has its temperature reduced, it continues to contract with more or less regularity, till it reaches the point at which it becomes solid. In becoming concrete, however, instead of following the general law, and contracting, it in many cases expands, and in some fluids, particularly water, its expansive force is very great. This expansion has been attributed to the extrication of a portion of air, which the fluid held dissolved in it. This has sometimes a share in producing the effect, but it is not the sole cause; since it still takes place when the fluid has been previously freed from

from air, or in fluids which contain none. It has been explained on the supposition that the particles of the fluid have a certain polarity, or tendency to unite by certain sides in preference to others, when they assume the solid state, and thus run into lines, applied to each other at a certain angle, by which the volume is increased.

Water affords a still more singular exception. It not only, in common with other fluids, expands in becoming solid, but it does so, even for several degrees, before it arrives at its freezing point. This expansion begins about the 40th degree of Fahrenheit. Previous to its temperature being reduced to that point, its volume diminishes as caloric is abstracted from it; but when it has fallen to the 40th degree, it begins to expand, and it continues expanding, while its temperature is reduced to 32, at which it freezes. The cause of this singular phenomenon has not been pointed out.

There is only one other exception to the expansion of bodies from the entrance of caloric,—that of the peculiar earth termed Argil, which is the principal constituent part of the natural clays.

clays. It, and the several compounds in which it predominates, contract by increase of temperature.

With these exceptions, all bodies which have not their composition or texture changed by caloric, suffer expansion from its introduction, and contract again when it is withdrawn.

From the increase of volume in bodies from caloric, it is evident that their temperatures must be attended to in estimating their specific gravities ; since a given volume of any body at a high temperature, must weigh less than the same volume at a low temperature.

FLUIDITY.

THIS is the *second* general effect produced in bodies by the entrance of caloric. When a solid is heated, it is expanded ; as its temperature is raised, this expansion proceeds, till its particles are separated to such distances as to be easily moveable in every direction : this constitutes fluidity. By a reduction of temperature the particles again approach ;

approach ; when within certain distances they unite, and the fluid is brought back to the solid state.

These changes of form depend on the actions of two opposite powers upon matter. By the mutual attraction, or force of cohesion, which subsists between the particles of bodies, they are held together so as to form solid masses ; by the repulsive power of caloric, they are separated to distances at which this attraction ceases. When the former force predominates, the body exists in the solid state ; when the latter prevails, it passes into the fluid form. Fluidity, therefore, is not essential to any species of matter, but always depends on the presence of a quantity of caloric. Solidity is the natural state of every body ; and there can be no doubt that every fluid is capable of being rendered solid by a due reduction of temperature, as every solid may be fused by the agency of caloric, if the caloric does not decompose them at a temperature inferior to that which would be necessary for their fusion.

Fluidity differs from expansion in the mode in which it is induced. Expansion is produced

duced gradually, there being as many degrees of it as there are degrees of temperature; while fluidity is in general sudden, and always takes place at a precise temperature.

In the reduction of fluids to the solid state, there are some circumstances which have an influence in producing the change, independent of the mere abstraction of caloric. These are agitation, and the introduction of a solid particle of the same kind of matter; a fluid, water for example, may, by carefully avoiding agitation, be cooled several degrees below the temperature at which, without this precaution, it would become solid; but the instant it is agitated, its congelation begins, and its temperature rises to that of its usual freezing point. The same effect is produced by bringing in contact with the fluid a solid particle of the same matter, as in the case of water, by placing a particle of ice on its surface.

These phenomena have been explained, on the supposition that the congelation of water, and other examples of a similar kind, are cases of crystallization; and that the agitation, by changing the situations of the particles, places some of them

them in these positions in which they are disposed to unite. The contact of the solid particle favours the freezing, by affording a nucleus, whence the crystallization may commence.

During liquefaction, a quantity of caloric is absorbed by the body, which does not raise its temperature; an important chemical phenomenon, the explanation of which must be referred, until the question respecting the quantities of caloric which bodies contain, is considered.

OF VAPORISATION.

WHEN a body has been rendered fluid by caloric, by the farther addition of this power, the fluid is expanded in the same manner as when it existed in the state of solidity. This expansion continuing to increase as the temperature is raised, the particles of the body are at length separated to such distances, that a change of form again takes place; the attraction of cohesion is entirely overcome, a repulsive or elastic power is acquired, and the body becomes invisible, or passes into the aeriform state. This is the *third* general

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effect of caloric. It is properly termed Vaporification; the body existing in this state is termed Vapour, Air, or Gas.

Some solids, by an increase of temperature, are converted into vapours without passing through the intermediate state of fluidity; but when heated under a greater pressure than that of the atmosphere, these also may be rendered fluid.

The distinguishing property of bodies existing in the gaseous form is Elasticity, or the capability of being reduced into less volume by pressure, and of expanding again when that pressure is removed. All the vapours and airs possess it, and it is nearly peculiar to them. This elasticity is much augmented by increase of temperature, and it is often exerted with very great force. Their compressibility also is very great.

Rarity is another property distinguishing bodies in this form. This rarity is so great, that their particles are perfectly invisible. Vapours in the act of condensation become opaque, and some of the gases are discernible by their colour.

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It is scarcely necessary to add, that Gravity is a property possessed by all the vapours, or gases, since they are all solid matters, brought into this form by the action of caloric. Their specific gravities, however, although different from each other, are much inferior to that of any fluid.

The point at which bodies pass into the gaseous state is very various. Some assume it at so low a temperature, that even the most intense cold that has been produced is insufficient to reduce them to the fluid form; others are convertible into vapour at a moderately high temperature, and condense again when that temperature is reduced; while there is a third class of bodies, the metals and earths, for example, not convertible into vapour but by the most intense heat; there are even some of them which have not suffered this change. These are termed Fixed, in contradistinction to those which are volatile, or easily convertible into vapour: but the term is merely relative; as there can be no doubt that even these bodies are volatile, though it may be at a higher temperature than has hitherto been produced.

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This difference in the temperatures at which bodies assume the aerial form, has given rise to a distinction established in chemical language---that between vapours and airs or gases. Vapours are those light invisible elastic fluids which, by cold or pressure, can be reduced to the liquid form. Airs, or Gases, (for these two terms are synonymous) are likewise invisible and elastic; but their elasticity is permanent, or they cannot by any cold or pressure which we can command be deprived of their aerial form. Atmospheric air is one of these permanent gases; and there are a number of others, distinguished from each other by peculiar chemical properties.

The same opinion has been entertained of the nature of the aeriform state, as was once maintained respecting fluidity. It has been considered as natural or essential to those bodies which exist in it. But modern Chemistry has sufficiently demonstrated, that the airs owe their form to the presence of caloric; that could this be sufficiently abstracted, they would, like the vapours, be reduced first to the fluid, and then to the solid state, and that they differ from these vapours in nothing, but in assuming the
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the aeriform state at a temperature extremely low. It is probable that means will be discovered of producing temperatures still lower, so that these bodies may be deprived of their gaseous form; two of them indeed, which were believed to be permanently elastic, have, by extreme cold and pressure, been reduced to the fluid state; and as we have succeeded in freezing mercury and ether, which were once regarded as essentially fluid, Chemists may succeed in condensing atmospheric air, or other gases, and thus discovering their solid bases. By causing them to enter into combination with each other, or with other bodies, we obtain compounds in the fluid or solid form; and such combinations are always accompanied with the disengagement of a large quantity of caloric.

The transition of bodies to the aeriform state is much influenced by the pressure of the atmosphere. It resists the expansion of their bases from the agency of caloric: hence, to produce this change of form, a greater rise of temperature is necessary when that pressure is present, than when it is removed; and by increasing the pressure, fluids may be heated to a very intense degree. On this influence of pressure on vaporisation,

tion, depend the variations in the boiling point of fluids, from the varying pressure of the atmosphere.

Bodies, in passing into the aeriform state, absorb a large quantity of caloric, which does not increase their temperature;---an important chemical phenomenon, which is to be immediately explained.

Although the attraction of aggregation, which is so powerful in counteracting the exertion of chemical attraction, is entirely overcome in bodies existing in the gaseous form, yet contrary to what we should expect, we find in them no great facility of combination; on the contrary, as has been observed in treating of the influence of caloric on chemical attraction, they combine in many cases with difficulty, and only at a very high temperature. How are these circumstances to be explained?

The cause of the first singularity, the difficulty of combination between bodies in the aerial form, is probably the great distances at which their particles are placed. Each solid particle in a gas is undoubtedly placed at a considerable distance from

from the others, by the repulsive power of caloric : when two gases, therefore, are mixed, the particles of the one must remain at a distance from those of the other ; and as chemical attraction is exerted only within a certain distance, no combination can take place between them. Hence we find, that in the vapours, the facility of combination is much greater than in the gases, because in the former the particles are less separated, and there is beside a perpetual tendency to condensation ; that even amongst those of the permanent gases between which a strong chemical attraction exists, the repulsive power is overcome, and the particles brought into union ; and that a union is in general more easily effected between a gas and a body in the fluid or solid form, than between two gases ; since the particles of the one, being less separated from each other, may be brought more nearly in contact with those of the other, and therefore any attraction existing between them may be more effectually exerted.

Another question more difficult remains to be solved. How does the introduction of more caloric operate in effecting the combination of bodies in the gaseous form ? Two gases may be mingled together without shewing any tendency
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to unite ; but if a spark be introduced into the mixture, either from an ignited body, or from electricity, their combination takes place with rapidity. Yet by such means we should rather suppose, that a greater expansion would be produced, and the particles separated to greater distances.

Is the following hypothesis adequate to the solution of this difficulty? When a spark is introduced into the mixture of two gases having an attraction to each other, the point on which it falls is immediately heated to an intense degree ; whence an expansion, proceeding from that point as from a centre, is produced ; and this expansion, by the pressure it must occasion on the surrounding particles, will cause them to approximate, and thus to unite. The whole effect is instantaneous, and it is upon the sudden operation that it depends. Were the caloric to be slowly introduced, the expansion would be slowly extended over the whole mass, and would be equal throughout ; the particles, therefore, would be still farther separated. But a single point being merely heated to a high degree, while the surrounding particles remain at their usual temperature, the expansion from the former must suddenly press

press upon the latter, much more quickly than the temperature can be communicated. These, therefore, instantly approximate within the verge of chemical attraction, and thus the union must be effected. After it has taken place, more caloric is rapidly, but successively, extricated by the combination itself, which will of course produce a similar effect on the remaining mass, till the combination is completed. There are some gases, however, from the union of which so little caloric is extricated, that the introduction of a single spark is insufficient, and therefore a stream of sparks must be kept up.

OF THE PROPAGATION OF CALORIC.

ALL bodies are permeable to caloric, and it has a constant tendency to diffuse itself over matter, till an equilibrium of temperature is established. It is impossible to accumulate it in any body beyond a certain extent, or to preserve it in that accumulated state. If a body, at a high temperature, is placed amongst a number of others at a low temperature, the excess of caloric which it contains passes off from it, till it arrives at the same

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temperature

temperature with those around it : and in like manner, when a cold body is placed among others that are hot, it continues to receive caloric from them, till its temperature rises to an equality with theirs. This propagation of caloric takes place even through the Torricellian vacuum ; and it is evidently owing to its repulsive power which constantly tends to an equilibrium.

Bodies, in receiving or parting with caloric, do so with very different degrees of celerity ; some being quickly heated, and as quickly cooled ; others undergoing these changes much more slowly. If a number of bodies be exposed to a common source of caloric, they will all at length arrive at the same temperature, but some will do so much more quickly than others : and if after they have attained this common temperature, they be removed from the source whence they received caloric, the same difference will be observable in the celerity with which their temperatures fall. Each body always receives and parts with caloric with the same celerity.

The permeability of bodies to caloric is termed their Conducting power. Those which receive and part with caloric quickly, are said to be
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better conductors of it, than those which receive and part with it more slowly. In general, the conducting power is nearly as the density of bodies ; those which are rare and porous, being less perfect conductors than those which are more dense. Thus the metals are the best conductors. But to this general rule there are many exceptions. The best conductors of electricity are also the best conductors of caloric, though neither is this correspondence uniform. The existing temperature has a considerable influence on the conducting power ; caloric being transmitted through the same body at different temperatures, with different degrees of celerity : at a high temperature it parts with it much more rapidly than it does at a low temperature. The celerity with which any body is heated or cooled, is *cæteris paribus*, proportioned to the extent of contact with the body by which caloric is added or abstracted. Hence the same matter, when in masses of equal weights, but of different figures, have their temperatures altered with different degrees of celerity.

From the difference amongst bodies in their power of conducting caloric, arises the great difference in the sensation excited by their application,

tion, when at the same temperature, to our organs. The sensation of cold is produced by whatever abstracts caloric from the part to which it has been applied; and of two bodies at the same temperature, the one which is the best conductor of caloric will abstract it most rapidly, and therefore occasion a more intense sensation of cold. The sensation of heat, again, is produced by whatever communicates caloric to our organs; that body, therefore, which is the best conductor, will also part with a larger quantity in a given time; and therefore, when applied hot, will excite a greater sensation of heat, than another will do at the same temperature, which is a worse conductor. Hence a piece of metal at a low temperature, appears to be much colder than a piece of wood, tho' their temperatures are shewn to be the same by the thermometer; and on the contrary, it will at a high temperature appear likewise to be hotter than the other.

Many useful applications are made of this difference in the permeability of bodies to caloric; as in the different contrivances to prevent the waste of heat in chemical operations, or to guard against the effects arising from the sudden alterations of temperature. The cause of the warmth
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of different kinds of clothing is likewise to be explained from this difference of conducting power.

The preceding observations apply only to the conducting power of solids. With respect to fluids two opinions are at present entertained; one which considers them as capable of conducting caloric, though very imperfectly; the other which supposes them absolutely impermeable to this power.

When caloric is distributed over any mass of matter, we conceive of it as passing from one particle to another, and this constitutes the conducting power, this being more or less perfect as the passage of the caloric is more or less rapid. In this way it was always imagined, that caloric might be distributed through fluids, as well as solids; at the same time it was allowed, that the distribution through the former was, in part at least, effected in another mode. When a body has its temperature raised, it is expanded or increased in volume, and consequently its specific gravity becomes less. If a portion of any fluid, therefore, be heated, it must change its place and rise to the surface, another portion must come into contact with the part from which the caloric is communicated, be heated, and ascend;
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and thus the whole mass is successively brought into contact with that part, till a common temperature is formed, or the fluid is evaporated.

In both these ways caloric was conceived to be diffused over any mass of fluid. The part which is heated ascends, and another portion comes to be heated. At the same time it was supposed, that the caloric is also communicated from one part of the fluid to the other parts with which it comes in contact, and thus the temperature of the whole is raised more quickly than if it were distributed merely by the successive applications of the fluid to the heated surface. It was also supposed, that the conducting power of different fluids is very various; and experiments were instituted to ascertain these differences.

In opposition to this opinion, Count Rumford has lately endeavoured to shew, that caloric is propagated thro' fluids solely in one of these modes, by the successive applications of the fluid to the heated part; and that the portion which is heated gives none of its caloric to the rest of the mass. "Although the particles of any fluid individually
" can receive heat from other bodies, or commu-
" nicate

"nicate it to them; yet among these particles themselves, all *interchange* and communication of heat is absolutely impossible." Fluids, therefore, are perfect nonconductors of caloric.

Count Rumford was led to adopt this opinion, from observing, that when a fluid is heated, very rapid ascending and descending currents are produced in it; and that when the motions of its particles are impeded from its viscosity, or from the intermixture of solid matter, caloric is propagated through it with extreme slowness. These facts he establishes by numerous and striking experiments.

He has also endeavoured to establish it by more direct proof. It is evident, that if his opinion be just, a fluid cannot be heated downwards; that is, if a heated body is applied to the surface of the fluid, the portion in contact with it will be heated, but, according to the opinion, it cannot communicate caloric to the fluid beneath it, and it will not change its place, since, by being heated, its specific gravity is diminished, so that it necessarily must remain occupying the upper part: hence no change of temperature can take place through the mass.

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The researches of Count Rumford on this subject afford very striking results. He found that water may be heated so far that it shall boil in the upper part of a glass tube, while that beneath has not its temperature sensibly increased ; that water may be even made to boil within 1-4th of an inch of a surface of ice, without immediately melting it ; and that ice fixed at the bottom of a cylindrical vessel, filled with boiling water, melts more than *eighty times* slower than when it is allowed to swim on its surface. Nor would it even melt at all, Count Rumford supposes, were it not for the singular property possessed by water, that when its temperature is reduced below 40° , a farther reduction of temperature down to 32° does not diminish its volume, but occasions a degree of expansion. Hence when the water in contact with the ice has its temperature reduced below 40° or 39° , it does not remain covering it, but becoming specifically lighter ascends. Its place is supplied by water, whose temperature is superior by one or two degrees to 40 ; and thus the whole mass of water, after a certain length of time, is successively brought into contact with the ice, and communicates to it caloric, by which it is at length melted. From this singular fact,
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Count Rumford drew the conclusion, that if water be a non-conductor of caloric, a quantity of it at the temperature of 40° , must be able to melt as much ice in any given time, *when standing on its surface*, as an equal volume of water at any higher temperature, even though it were boiling hot; a conclusion which, on experiment, he found to be just.

Count Rumford made a variety of other experiments, to prove that caloric cannot be communicated from one body to another, if a small quantity of any fluid, as of water, oil, or mercury, intervene, and if no part of that fluid change its place. From the whole he concludes, that fluids are absolutely non-conductors of caloric.

It is difficult to determine whether this conclusion is strictly just, or whether fluids only conduct caloric with extreme slowness. Although the greater number of Count Rumford's experiments do no more than establish the latter conclusion, yet there are some of them, those particularly which were made to prove that caloric does not descend through fluids, the results of which seem inconsistent with the supposition, that a body in the fluid form possesses any conduct-

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ing power. The experiments of other Chemists, it is true, have been less favourable to Count Rumford's conclusions ; but all experiments of this kind are liable to sources of fallacy, the effects of which are much greater than we should *a priori* expect, and against which it is extremely difficult to guard. In performing the experiment, which is the only one perhaps calculated to decide this question, *that* designed to ascertain whether caloric descends thro' fluids, --- independent of other sources of error, it is scarcely practicable to prevent the caloric from being conducted by the sides of the vessel. If a quantity of any fluid be put into a cylindrical glass vessel ; and if a thermometer, bent so that its ball shall be higher than that part of its stem to which the scale is attached, be placed at some depth in it ; and if a hot fluid of a specific gravity inferior to that of the other, be poured over its surface, it is evident that this fluid, coming immediately into contact with the sides of the vessel, will give to them part of its caloric. This will be conveyed downwards, and be immediately again given out to the colder fluid in contact with the internal surface of the glass ; this, being expanded, of course tends to rise, and must extend itself, so as to form a stratum, which is continually augmenting. The
thermometer

thermometer is thus heated, sooner or later, according to the distance between it and the hot fluid. If instead of a hot fluid, a solid, as a ball of iron heated, be suspended in the cold fluid, still as it must give out caloric to the portion of fluid in which it is immersed, the sides of the vessel will be heated, though more slowly, and of course the same source of error will be introduced. If, to obviate this, the vessel in which the thermometer is put, be placed in another filled with a cold fluid, though the quantity of caloric conveyed by the sides of the internal vessel will thus be lessened, it cannot be entirely prevented, since it must still give out as much caloric from its internal as from its external surface.

Every precaution that is taken to obviate this source of error, such as employing a solid body as the medium for conveying caloric, using a very wide vessel to contain the fluid in which the thermometer is placed, or placing the thermometer at a distance from the heated body, tends equally to lessen the effect which would result from the conducting power of the fluid, supposing it to possess such a power; and hence the difficulty of conducting the experiment so as to obtain a certain result. On performing it with every precaution,

tion, I have found the rise of temperature indicated by the thermometer so minute, that it could scarcely be affirmed with certainty, whether it was produced by the conducting power of the fluid, or by the communication of caloric from the sides of the vessel. When the thermometer was placed in the centre of a glass vessel eight inches in diameter, and water poured in till it covered the bulb two inches, on suspending over it, and at the distance from it only of $\frac{1}{4}$ inch, a plate of brass, three inches in diameter, and $\frac{3}{4}$ inch thick, heated to 212° , no rise was perceived for ten minutes; in 20 minutes it had risen about one degree, and in 30, $1\frac{1}{2}$ degree, at which it became stationary, and continued at this point for fifteen minutes before it began to fall. In another experiment, the thermometer was placed in a jar, only three inches in diameter, and its bulb covered with water to the depth of one inch. This was placed within another vessel, into which water was poured, to the same height as in the inner one, and a thermometer was suspended in it, to the same depth in the fluid. A ball of iron $1\frac{1}{2}$ inch in diameter, was suspended over the bulb of the thermometer, in the inner vessel, at a distance of $\frac{1}{6}$ th of an inch. The mercury soon began to rise slowly; and in twenty minutes it had
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risen 6 degrees, when it became stationary. That the caloric, however, which occasioned this rise of temperature, was conveyed principally or solely by the sides of the vessel, was proved by the other thermometer rising nearly at the same time, and rising to the same extent. From these experiments, it does not appear that the conclusion can fairly be drawn, that fluids are capable of conducting caloric: they are rather more favourable to the opposite opinion.

It had been known, that bodies existing in the aerial form are very imperfect conductors of caloric. Count Rumford holds the same opinion with respect to them as with respect to liquids: they may receive caloric from other bodies, either solid or fluid; but he supposes they are incapable of communicating it from one particle to another, and therefore that the change of temperature in any mass of matter existing in the form of vapour, or gas, arises solely, as in fluids, from the motion of its parts, produced by the alteration in the specific gravity which the communication of caloric occasions. The experiments in support of this opinion are the same in principle as those by which the non-conducting power
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of liquids is established ; and the same conclusion is probably to be drawn from them.

To this impermeability of aeriform substances to caloric, the property which spongy bodies have, of suffering changes of temperature very slowly, is owing. All light porous substances, as furs, feathers, wool, and down, contain a large quantity of air in their interstices. As it cannot conduct caloric, and as the motions of its particles by which it might transport it are much retarded, these substances are very imperfect conductors ; they therefore furnish the warmest clothing, as they confine most effectually the heat of the body, and prevent it from being abstracted by the surrounding colder atmosphere.

Though fluids, elastic and non-elastic, are incapable of conducting caloric, or conduct it with extreme slowness, they are still, by their power of transporting it, active agents in heating and cooling bodies ; and it is by their means that the general distribution of caloric is regulated, and the temperature of the globe rendered more uniform. The atmosphere and the ocean chiefly serve the important purpose of moderating the extremes of temperature, whether of heat or cold,

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in every climate. Different fluids and airs, from differences in their specific gravities, their expansibilities, and their consistence, will transport caloric with different degrees of celerity, and will consequently differ in the rapidity with which their temperatures are changed, or with which they change the temperatures of other bodies. Different bodies too, existing in the fluid or aerial form, although all perhaps equally incapable of conducting caloric through their substance, differ much in the rapidity with which they receive it from any other body, or with which they give it out, which gives rise to differences in their apparent conducting power. Mercury, for example, receives caloric more rapidly than water does, and of course parts with it more quickly : hence, at a low temperature, it excites a feeling of cold, and at a high temperature a sensation of heat, much stronger than water does. Mercury likewise receives caloric more quickly than alkohol : hence the thermometer with the one shews the temperature of any body applied to it, sooner than that with the other.

From the combination of these circumstances, of the consistence of fluids allowing a free motion of their particles, of the greater or less change produced

produced in their specific gravities by change of temperature, and of the various degrees of celerity with which they abstract caloric from other bodies, or give it out, different fluids will be heated or cooled with different degrees of celerity, though they may all be non-conductors of caloric: and on these differences many important natural phenomena depend.

Besides these modes, in which changes of temperature amongst bodies are propagated, either by caloric being communicated from particle to particle, or by its being transported by change of place in the matter which receives it, or from which it is abstracted, there is still another mode, that by Radiation, or projection from the surfaces of bodies, in right lines, with extreme velocity.

This property of caloric had been noticed by Mariotte, Lambert, and Scheele, but has been more clearly established by the experiments of Sauflure and Pictet. They placed two concave tin mirrors opposite to each other, at the distance of twelve feet. When a hot body, a ball of iron for example, was placed in the focus of the one, and a mercurial thermometer in that of the other;
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the mercury immediately began to rise, and continued to ascend for several minutes. An iron ball, 2 inches in diameter, heated so far that it was not luminous in the dark, raised the mercury not less than $10\frac{1}{2}$ degrees of Reaumur's scale, in 6 minutes: a lighted candle occasioned a rise in the thermometer nearly the same: a glass matras, containing 2 ounces 3 drams of boiling water, raised Fahrenheit's thermometer 3 degrees. The increase of temperature was still greater when the ball of the thermometer was blackened.

These experiments prove, that from bodies at a high temperature a matter is thrown in right lines, capable of reflection and concentration, which raises the temperature of any body on which it falls.

This matter, it has been farther proved, passes with the greatest velocity, equal to that of light; it is retarded in its passage by the atmospheric air, and by transparent fluids, as water, and it is scarcely capable of penetrating glass. It has also been shewn by Dr. Herschel, that it is capable of refraction.

Saussure and Pictet drew the obvious conclusions from these experiments, that this matter was of the nature of caloric, and that it was merely that subtle fluid in a state of radiation. The phenomena have, however, been attempted to be explained in a different manner. Dr Hutton conceived it to be an unphilosophical assumption, that caloric could be capable of radiation; he therefore endeavoured to prove, that light is the agent concerned in these experiments.

It is known that the rays of light, when they fall upon opaque bodies, have the power of raising their temperature. Dr Hutton assumes, as the basis of his explanation, that the power which the different species of light have of heating bodies, is not proportioned to the power of exciting vision, but that there are some rays more powerful in exciting this sensation than in producing heat. "The compound light, for example, which is white, has a greater power of giving vision, in proportion to its power of exciting heat; whereas in the red species, it is the opposite: for here the power of exciting heat is great in proportion to its power of giving vision." †

Dr.

† Hutton on the Philosophy of Light.

Dr. Hutton, assuming this principle, further supposes, that a species of light may be radiated from bodies, capable of raising the temperature of any substance on which it falls, but not discoverable by illumination. And what has been termed Radiant caloric, he supposes to be merely light of this kind.

This opinion is founded on the similarity in the motion of light, and of this radiant caloric. It is supposed to be improbable, that the same matter should be capable of two kinds of motion; that caloric should be slowly propagated by emanation from one body to another; and that another portion of it should, at the same time, be thrown off in a rapid projective motion. And as this radiant caloric observes in its motion all the laws peculiar to light, since, like it, it is found capable of reflection, and even of refraction, we may suppose with justice their identity, if from this supposition the phenomena in question can be satisfactorily explained.

The assumption from which this opinion originated, that caloric cannot, without absurdity, be supposed capable of radiation, is entirely gratuitous. There is no necessary connection between

tween the proposition that light radiates and the conclusion, that caloric must be incapable of radiating. It is indeed sufficiently evident, that although light alone has been hitherto observed to radiate from bodies, it does not follow that no other subtle matter may not move in the same manner. The present question cannot therefore be decided by such reasoning, but only by ascertaining the properties of this radiating matter; and thus determining whether, upon the whole, these properties are more analogous to those of caloric or those of light.

It will be observed, that the resemblances which have been noticed between this matter and light, relate merely to the mode in which it is moved, in other words, to their mechanical properties, their being alike capable of radiation, reflection, and condensation. But these points of resemblance, are insufficient to identify them, unless it were first proved, that light alone is capable of radiation.

A circumstance which has been supposed to establish their identity is, that the augmentation of temperature, from the radiant caloric, is much greater, when the bulb of the thermome-

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ter on which it is thrown is blackened, than when it is not. This circumstance appears to connect it closely with light, since the heat which light excites is always greater in bodies of a dark colour, than in those which are of a lighter shade; and accordingly Dr. Hutton styles this the *experimentum crucis*, in support of his opinion. But what is the cause of this peculiarity in the heating power of light? It is, that its particles undergoing numerous reflections and refractions, in the pores of dark coloured bodies, it is retained more completely, whilst when it strikes upon those of a lighter colour, it is in a great measure reflected from their surface. But if it is assumed, that caloric is subject to the same laws of motion as light, and is capable, like it, of reflection and refraction, the same effect ought to follow, when it is thrown by radiation upon a black body; and the circumstance that this actually happens, does not tend more to identify radiant caloric with light, than the more general fact, which necessarily must be assumed, that they move according to the same laws. This peculiar circumstance, therefore, furnishes no *additional* argument for their identity, nor does it extend the analogy between them.

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There are several properties in which radiant caloric differs widely from light, so much so as to render improbable the conclusion, that they are the same.

In the first place, the caloric rays are incapable of exciting vision; nor is this owing to their tenuity, since, when concentrated, they still do not produce any sensible illumination.

Again, light passes with facility through rare media, through transparent fluids, and through glass; but this radiant matter, it is shewn by the experiments of Pictet, is retarded in its passage even by the atmosphere, it does not pass through fluids, and is scarcely capable of penetrating glass, while it heats it considerably. If we suppose it analogous in its nature to light, these differences are not accounted for: if it is supposed to be analogous to caloric, they are at once explained, since the caloric, passing through the air, and still more through glass, must in part be retained.

A still more important difference between light and caloric seems to exist with respect to their chemical qualities. Light possesses certain chemical properties, by which it is characterised

as a peculiar kind of matter. Sennebier long ago remarked, that the different rays of light possessed the same chemical properties in a very different degree; that the violet, for example, produced a peculiar chemical effect, that of blackening the muriat of silver in fifteen seconds, while the red did not produce the same effect in less than twenty minutes. The late valuable experiments of Dr. Herschel have shewn that in the red rays, along with visible light, there is intermixed a large proportion of radiant caloric, while the violet rays contain scarcely any of it, but are nearly pure light. By these facts, therefore, it is rendered extremely probable, that radiant caloric does not possess the chemical properties by which light is characterised; and I have accordingly found by experiment, that the radiant caloric emitted by bodies at a high temperature has no effect, like that of light, in darkening the colour of muriat of silver. But if a distinction is to be established between two bodies, it is evident that it must be drawn chiefly from the comparison of their chemical properties: if these differ, the conclusion follows that they are different kinds of matter.

Lastly, it may justly be questioned, whether light possesses any power of heating bodies; and if
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it do not, it is evident that the hypothesis advanced by Dr. Hutton cannot be applied to the explanation of the phenomena of radiant caloric. The late experiments of Dr. Herschel appear at first view to be favourable to Dr. Hutton's opinion, since they establish the truth of the supposition on which it rests, that the different visible rays have different heating powers; they shew that the red rays are much more powerful in this respect than the green, and the green still more than the blue, or the violet. But by further pointing out the cause of this difference, they afford the strongest argument which can be urged against it. These experiments prove, that in solar light a matter exists, which, without being capable of exciting vision, is powerful in producing heat,---a matter which is capable of reflection, refraction, and condensation, and is indeed nothing else than radiant caloric. When a solar beam is decomposed by the prism, these caloric rays being less refrangible than any of the visible rays, are in a great measure separated from them, and being also of different degrees of refrangibility are extended over a considerable space. It is found, that the heating power discoverable in the prismatic spectrum is greatest in that point where this invisible caloric matter is accumulated, and
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that it diminishes from that point towards the more refrangible visible rays, till in the violet, which are the most refrangible, and which are of course at the greatest distance from the invisible caloric matter, it is extremely weak. It is evident, that since in the solar light, a matter exists different from visible light, which is powerful in exciting temperature; since this cannot be perfectly separated from the visible rays, and since the more completely it is separated, the less heating power do these possess, the supposition that light, apart from this radiant caloric, has any power of raising the temperature of bodies, is not only unsupported by any proof, but the opposite conclusions follow as extremely probable, that pure light is destitute of any such power, and that it is on the presence of this invisible caloric matter that the heating quality of the solar rays depends. But if these conclusions be admitted, it is evident that the hypothesis of Dr. Hutton must be relinquished, since the phenomena of radiant caloric can never be explained on the supposition that it is a species of light, if light itself has no power of augmenting temperature.

From the consideration of these facts it may be concluded, that the peculiar invisible caloric

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matter

matter which has been found to be emitted in right lines from heated bodies, and which is also present in the solar rays, is rather caloric than light, since its properties are more analogous to those of the former than those of the latter.

Or, perhaps, what is termed Radiant caloric may be merely caloric combined with a quantity of light, to which it may owe its capability of radiation, reflection and refraction, while it still retains its heating power; nor is it improbable, that even the different visible rays may be composed of pure light, to which different quantities of caloric adhere, and that from this may be derived the difference which exists in their power of raising the temperatures of bodies. The violet ray will thus be light in its purest form, while the red ray will have the largest proportion of caloric, and will therefore approach most nearly in its properties to radiant caloric.

Pictet discovered another very singular fact respecting the transmission of caloric,—the apparent radiation and reflection of cold. When, instead of a hot body, a matras full of ice or snow is placed in the focus of one of the mirrors, the thermometer in the focus of the other immediately

ately falls, and ascends again whenever the cold body is removed.

This phenomenon may be explained on the supposition, that from every body at every temperature caloric radiates, but in less quantity as the temperature is low ; so that, in the above experiment, the thermometer gives out more caloric by radiation, than it receives from the body in the opposite focus, and therefore its temperature falls : Or, as Mr Pictet has supposed, when a number of bodies near to each other have the same temperature, there is no radiation of caloric, because in all of them it exists in a state of equal tension ; but as soon as a body at an inferior temperature is introduced, the balance of tension is broken, and caloric begins to radiate from all of them till the temperature of that body is raised to an equality with theirs. In the above experiment, therefore, the placing the snow or ice in the focus of the one mirror causes the radiation of caloric from the thermometer, and hence the diminution of temperature which it suffers.

OF THE COMPARATIVE QUANTITIES OF CALORIC WHICH BODIES CONTAIN.

IN homogeneous bodies, the quantities of caloric which they contain are proportioned to their temperatures and quantities of matter. If one pound of any substance at a certain temperature contain a certain quantity of caloric, two pounds of it will contain double the quantity, or one pound, at the temperature of 100° , will contain double the quantity which one pound at the temperature of 50° does: hence when equal quantities of a homogeneous body at different temperatures are mixed together, the temperature which results is the arithmetical mean between their respective temperatures previous to mixture. That this should be the case is nearly evident *a priori*; for the particles of different portions of the same matter being alike, their powers must be equal. There is no cause why one portion should have a relation to caloric different from the other, or require a different quantity to raise its temperature.

It might be supposed that the same law would be observed in the distribution of caloric in heterogeneous bodies, that the quantities of it which they contain would be proportioned to their temperatures

peratures and quantities of matter, --- in other words, that any number of bodies at the same temperature would, in equal weights, contain equal quantities of caloric.

On making the experiment, however, this is not found to be the case. If a number of bodies of different kinds, alkohol, oil, mercury, water, and others, in equal quantities, and at the same temperature, be exposed to a common source of caloric, they will all receive it, and in a certain time arrive at a common temperature. But it will be found, that in arriving at this temperature they have absorbed very different quantities of caloric; the water will have taken in more than the alkohol, and this more than the others. It is evident, therefore, that altho' we suppose that at the beginning of the experiment they contained equal quantities of caloric, they must at the temperature to which they are raised contain unequal quantities. But the same cause that disposes one to absorb more caloric than another continues always to operate; and it is accordingly found, that at every point in the scale of heat different bodies contain very different quantities of caloric, in the same weights and at the same temperatures.

Boerhaave

Boerhaave first inferred, from an experiment in which equal quantities of mercury and water at different temperatures were mixed, that these two fluids in equal weights contained unequal quantities of caloric. Dr. Black further shewed, that the quantities they contained were not proportioned to their volumes, as Boerhave had supposed; and by investigating this subject, he drew the general conclusion, which numerous experiments by other chemists have established, that the quantities of caloric contained in heterogeneous bodies at the same temperature, are proportioned neither to their weights nor volumes, but are in ratios which cannot be referred to any of the obvious qualities of bodies, and can therefore be ascertained only by actual experiments.

The general experiment by which the quantities of caloric which bodies contain are ascertained, is that of mixing together equal weights of two different bodies at different temperatures, and observing the temperature produced.

In homogeneous bodies, as has already been observed, the temperature produced by mixing equal quantities of them at different temperatures,
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is always the arithmetical mean between the temperature of each; the excess of caloric which the one contains above the other being equally divided between them, and producing the same rise of temperature in the one portion, as it does of reduction of temperature in the other. But when the same experiment is made with two heterogeneous bodies, the result is entirely different; the temperature produced never being the mean of the two original temperatures. Thus, if one pound of water, at the temperature of 156, be mixed with one pound of mercury at the temperature of 40, the temperature which results is not the arithmetical mean, 98, but is not less than 152. This proves that the change of temperature produced in the one by a certain quantity of caloric, is entirely different from that produced in the other by the same quantity; for the water in this experiment having had its temperature reduced from 156 to 152, has lost only 4 degrees; but these have raised the temperature of the mercury, not less than 112 degrees. The quantity of caloric, therefore, necessary to raise the temperature of one pound of water 4 degrees, is sufficient to raise that of an equal weight of mercury 112 degrees; or the quantity requisite to raise the temperature of one
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of these fluids one degree, raises the other 28. This will be the case at every temperature; and therefore at any point in the scale of heat, the quantity of caloric contained in water is to that contained in the same weight of mercury as 28 to 1.

If the experiment is varied by mixing water at a low, and mercury at a high temperature, the result is the same. If one pound of mercury, at 156, be mixed with one pound of water at 40, the temperature produced is 44. The mercury has been deprived of a quantity of caloric, which has reduced its temperature 112 degrees, and this quantity has raised that of the water 4. In this manner, when equal weights of two different bodies are mixed together, the temperature produced is always nearer to the temperature of that body which contains the greatest quantity of caloric, because it requires the greatest quantity to produce in its temperature any change. The proportion is also indicated by the experiment; the alterations of temperature, and the comparative quantities of caloric contained in different bodies, being reciprocally proportioned to each other.

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When, instead of comparing the quantities of caloric which equal *weights* of different bodies contain, we compare the quantities contained in equal *volumes*, we still find that a similar difference exists. Thus it is found by experiment, that the quantity of caloric necessary to raise the temperature of a given volume of water any number of degrees, is to that necessary to raise an equal volume of mercury the same number of degrees, as 2 to 1. This is, therefore, the proportion between the comparative quantities of caloric which these two bodies contain, estimated by their volumes; and similar differences exist with respect to every other kind of matter. The comparative quantities of caloric in bodies are usually estimated from equal weights of them; the experiments for this purpose being in general more easily executed, than these by which they are estimated from equal volumes.

The property by which different bodies contain their respective quantities of caloric, has been termed the Capacity for heat, or, to adapt the expression to the language of the established nomenclature, the Capacity of a body for containing caloric. This term is not designed to point out any particular cause, mechanical or

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chemical; neither does it express any vague obscure idea, as has been alledged. It is merely a general expression to denote the property which bodies have of containing, at the same temperature, and in equal quantities, either of weight or volume, certain quantities of caloric. That they do so, is unquestionable; there must, therefore, be such a property, and it is this which is termed the capacity for containing caloric.

It has not been discovered on what circumstances the difference in the capacities of different bodies for caloric depends. It is not invariably connected with any of their obvious qualities; for although in general, rare bodies have greater capacities than those which are more dense, the exceptions to this are extremely numerous. Oxygen gas, for example, has a specific gravity somewhat superior to that of azotic gas; yet its capacity, instead of being less, is greater in the proportion of about 5 to 1; and water has a capacity to that of mercury as 28 to 1, while the difference in specific gravity is only as 1 to 14. The capacities of bodies, therefore, cannot be estimated by their density, but must be determined by actual experiment.

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From the nature of the experiment by which the quantities of caloric which bodies contain are ascertained, it is evident, that we discover merely the comparative, not the absolute quantities. We find only how much caloric a body gives out, or absorbs, during a certain change of temperature; and by observing, at the same time, the change of temperature which the body from which it has received or to which it has given caloric suffers, we may ascertain the comparative quantities necessary to produce equal changes of temperature in these bodies. But we do not learn the proportion which the quantity in each bears to the whole caloric which it contains; and therefore the capacities of different bodies are to be considered as merely comparative. Hence it becomes necessary to fix on one body, as a standard to which the others may be referred. Water has been chosen as this standard; its capacity is stated at the arbitrary term of 1000, and with this the capacities of other bodies are compared. Thus the capacity of arterial blood is stated at 1030, indicating, that if at any temperature a certain quantity of water be supposed to contain 1000 degrees of caloric, the same quantity of arterial blood at the same temperature will contain 1030 degrees.

Water

Water has likewise been selected as the substance with which any body is mixed, when the capacity of this body is to be ascertained, and for this purpose it is the most convenient, from its mixing easily with the greater number of bodies, and not exerting in general any chemical action on them, which can modify their attractions. Where, from exerting such an action, it cannot be employed, mercury, oil, or alkohol, may be used.

This method of ascertaining the capacities of bodies for caloric, by mixing them at different temperatures, is liable to many sources of error, against which it is difficult entirely to guard. Substances having different specific gravities cannot be immediately intimately mixed together so that every part of the mixture shall attain the same temperature; and during the time employed in mixing them, a portion of caloric is abstracted by the vessel and the surrounding atmosphere. Hence the quantities of the bodies used in the experiment, the degree of agitation by which they are mixed, the celerity with which different bodies part with their caloric, their specific gravities, their miscibility with water, even the size and shape of the vessel, and the composition of the matter of which it is formed, have all an influence,

ence, more or less considerable, on the result. Dr. Crawford, in his excellent treatise on this subject, has given a number of cautions founded on these circumstances, and necessary to be attended to in making these experiments; but still errors, to a certain extent, can scarcely be avoided, and evidently give rise to the differences in the experiments of different chemists.

From considering the difficulties attending the method of ascertaining the capacities of bodies by mixture, and also that it is not possible to apply it to those bodies which, when mixed, exert a chemical action on each other, since such an action changes entirely the existing capacities; Lavoisier and Laplace proposed another method of ascertaining the comparative quantities of caloric in different bodies. This method is founded on the fact, that ice in melting absorbs a quantity of caloric, which is always the same. One pound of ice, for example, by whatever means it may be melted, absorbs a quantity of caloric equal to what would raise the temperature of one pound of water 135 or 140 degrees of Fahrenheit's scale. If, therefore, any substance the temperature of which is higher than 32° of Fahrenheit, be supposed to be included in a sphere of ice, so that the caloric which it will
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give out shall be communicated entirely to the ice, and to it alone, from the quantity of ice melted, the quantity of caloric given out by a body during a certain reduction of temperature will be discovered, and of course its capacity will be ascertained. On this principle is constructed the *Calorimeter*, the instrument which Lavoisier and Laplace proposed. It consists of a tin vessel filled with ice, and which, to prevent the communication of caloric from the external atmosphere, is inclosed in another vessel likewise containing ice. The substance operated on is placed in a small cavity in the middle of the inner vessel: the water which is produced from the melting of the ice is measured when the experiment is completed.

It has been found, however, that this method of discovering the capacities is likewise liable to errors, particularly from the influence of the temperature of the atmosphere, from part of the water produced being retained in the pores of the ice by capillary attraction, and from the temperature not being uniform through the whole apparatus,---so that the two opposite processes of freezing and thawing sometimes go on at the same time. It is, therefore, very doubtful whether the

the results which have been obtained from it, are more accurate than those from the more simple mode of mere mixture.

The capacities of a great number of bodies for caloric have been ascertained by the experiments of Irvine, Crawford, Lavoisier and Laplace, Wilcke, Gadolin, and other chemists; and have served as the basis of many important applications to the explanation of chemical phenomena. From changes of capacity arise both the evolution and absorption of caloric which accompany chemical action, a rise of temperature being produced when the capacities of the substances acting on each other are diminished, and a reduction of temperature following from the reverse. On this principle are explained the extrication of caloric produced by combustion, respiration, and other chemical processes, and the absorption of it which takes place during the solution of salts in water, or the action of different salts upon each other.

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BESIDES the general law which has been demonstrated, that different bodies, in equal weights and at equal temperatures, contain unequal quantities of caloric, it has further been established, that a similar law exists with respect to different forms of the same kind of matter: a body in the fluid form contains more caloric, or requires a larger quantity to produce a given change of temperature in it, than it does while solid; and in the state of air or vapour, it contains still more caloric than it does in the fluid form. Hence, when a solid is melted, or a fluid is converted into vapour, a quantity of caloric is absorbed, which has no effect in producing augmentation of temperature.

This general fact was discovered nearly about the same time by Professor Wilcke of Stockholm, Dr. Black, and Mr. De Luc. It is one of the most important in chemistry, from the extensive applications of which it admits.

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Its truth is sufficiently evident, when the phenomena attending liquefaction and vaporisation are attentively examined. When caloric is communicated to a solid body, an increase of temperature is produced, and the temperature continues to rise while the caloric continues to be added, till the body arrives at its melting point : but whenever it begins to melt, the rise of temperature ceases, though the addition of caloric be continued as before ; and the fluid, as it forms, remains at one point till the fusion is completed. In this case then it is evident, that a quantity of caloric disappears ; for it continues to be added to the body, but has no effect in raising its temperature.

The case is the same when a fluid is converted into vapour. Its temperature is first raised to a certain point by the communication of caloric to it ; it then begins to assume the gaseous form : but though the communication of caloric be still the same, the temperature, neither of the fluid, which is evaporating, nor of the vapour formed, is raised, but remains stationary at that point in the thermometrical scale at which the conversion into vapour commenced, till the whole be evaporated. It is evident, therefore, that

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It was from considering these known facts, that Dr. Black concluded, that during liquefaction and vaporisation a quantity of caloric is lost, becomes latent, or passes into the body without raising its temperature---a conclusion which he established by the most simple but decisive experiments. He shewed, that when a piece of ice is exposed to a warm atmosphere, its temperature rises till it arrives at the 32d degree of Fahrenheit; but the rise of temperature then stops till the whole is melted, though it is all the time receiving caloric: and he found by calculation, that one pound of ice in melting absorbs not less than 140 degrees of caloric, the temperature of the water into which it is converted still remaining at 32°. This result he confirmed by adding directly to 1 pound of ice at 32° 1 pound of water at 172°. The ice was melted, but the temperature of the whole fluid, instead of being the mean 102°, was only 32°; 140 degrees of caloric had therefore

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In the conversion of bodies from the fluid into the aeriform state, a similar absorption of caloric takes place, though the temperature of the vapour still remains the same as that of the fluid from which it is formed. To demonstrate this by experiment, Dr. Black heated a quantity of water, in a strong phial, closely corked, till its temperature rose 10 degrees above 212° , its usual boiling point. On drawing the cork quickly, a small portion of water rushed out in vapour, and the temperature of the remaining fluid sunk instantly to 212° . Ten degrees of caloric, therefore, had been absorbed by the quantity of vapour that escaped. Mr Watt, by heating the water under a still stronger pressure, that of an iron vessel, raised its temperature to 400° ; yet still when the pressure was removed, only part of the water was converted into vapour, and the temperature of this vapour,

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The same general fact is farther proved by the great degree of cold produced by the evaporation of certain volatile fluids, as ether, alcohol, and even water, the fluid, in evaporating, absorbing a quantity of caloric from the surrounding bodies.

All these facts fully prove the truth of the general proposition, that when bodies pass from the solid to the fluid, or from the fluid to the gaseous form, a quantity of caloric is absorbed, which has no effect in raising the temperature of the fluid, vapour, or gas, which is formed.

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There is another experiment, in which the extrication of caloric from this cause is rendered sensible. By avoiding agitation, any fluid, water, for example, is capable of being cooled a number of degrees below its freezing point. If, when cooled thus far, it be agitated, it immediately becomes solid, and from the evolution of caloric which accompanies the change of form, its temperature instantly rises to that of its usual freezing point.

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By these facts the general truth is established, that "when bodies, in consequence of exposure to heat, have arrived at the melting or boiling points, they absorb a quantity of heat, which does not increase their temperature; and on the contrary, when vapours are condensed, or non-elastic fluids are congealed, they part with the heat which they had formerly absorbed." This portion of caloric is termed Latent, to distinguish it from that which contributes to preserve or raise the temperature of bodies, which is termed Sensible caloric. These terms are synonymous

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On this absorption of caloric attending change of form, many important chemical and natural phenomena depend ; as the uniformity and fixity of the freezing and boiling points, the slowness with which large collections of water are frozen, or large masses of ice are melted, the cold produced by evaporation, and the heat by condensation of vapour.

Different opinions have been entertained respecting the cause of this phenomenon which accompanies liquefaction and vaporisation. Dr. Black considered the absorption of caloric as the cause of the change of form, and as necessary to the constitution of the fluid or vapour. De Luc went a step further, and supposed that the absorption of caloric is a chemical combination of it with the substance melted or evaporated, and that to this combination the change of form is owing. Dr. Irvine proposed a third opinion, very different from these : he considered the absorption of caloric, not as the cause, but the consequence of the change of form, from the capacity of the body being enlarged.

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Of these opinions, that advanced by Dr. Black can scarcely be considered as opposed to that which ascribes liquefaction and vaporisation to a chemical combination of caloric; since, if the absorption and latent state of caloric be the cause of the change of form, it is probable that it is so by an action of this kind. It is this doctrine, then, of caloric entering into chemical union with the body fused or evaporated, that is to be considered as opposed to the explanation of Dr. Irvine. The former is the one which is generally received, but it is very doubtful whether it is founded in truth. It is founded only on some general analogies,--- principally on the analogical argument, that if caloric be matter, it must be subject to the laws of chemical; and that in the particular cases of liquefaction and vaporisation, the phenomena are similar to those which take place in the combination of other chemical agents.

The first of these arguments is of no force; for although the materiality of caloric should be admitted without dispute, yet it is certain that its properties and relations to other bodies are altogether peculiar; and therefore no argument can be established on its analogy to them, for no such analogy exists. We have every reason to believe

lieve that it is not subject to the attraction of gravitation, and we know that it is an antagonist to the attraction of cohesion. So far, therefore, are the properties it possesses from leading to the conclusion that it must be endowed with all the general properties and affections of matter, that they lead to the opposite conclusion: for if analogy is to have any weight, since caloric is not subject to the attractions of gravitation and cohesion, the presumption follows, that it will be also exempt from the influence of chemical attraction.

The other argument, that derived from the analogy between the absorption of caloric in the cases of liquefaction and vaporisation, and chemical combination in general, seems more conclusive, and it is the observation of this analogy that has given rise to the opinion. When one chemical agent is merely *mixed* with another, the properties of neither are altered; but when chemically combined, they are more or less changed; and this combination always takes place in certain determinate proportions. Caloric acts upon matter in a manner similar to this: it may be diffused through bodies to a certain extent without having its properties altered; but in liquefaction and vaporisation it is united to the body, so that its pro-

perties are entirely lost. Ought not this, in conformity to general analogy, to be ascribed to its having formed a chemical union ; especially since it is absorbed by different bodies in different quantities, but always in certain determinate proportions---circumstances which extend the analogy between this absorption and chemical combination ?

But though it seems so far complete, when more minutely examined it will be found extremely deficient. We know of no case of chemical combination in which the properties of one of the bodies combining are entirely lost, while those of the other are not altered ; but in liquefaction and vaporisation this must be supposed to be the case, since, though the properties of the caloric absorbed can no longer be recognised, those of the substance fused or evaporated remain the same. Every solid too may be rendered fluid, and every fluid converted into vapour ; and consequently it must be supposed, that caloric is capable of combining chemically with every other body,---a property possessed by no other chemical agent. And, lastly, the contact of any body at a low temperature is sufficient to reduce a vapour to fluidity, or a fluid to the solid state ; and in such cases,

cases, the caloric abstracted does not enter into combination with the body to which it is communicated, but is merely diffused through it so as to raise its temperature. But that union cannot be termed chemical which is not elective, and which can be so easily broken, one of the principles being abstracted without the interference of a stronger affinity.

The opinion of Dr. Irvine is better supported. Its principle, that a change of capacity takes place, is established by experiment, and it accounts satisfactorily for the phenomena.

That the absorption and latent state of caloric which take place in liquefaction and vaporisation, are fully accounted for by the supposition that the capacity is increased, cannot be doubted. If any body have a certain capacity, and if by any means the capacity be increased, nothing can be more evident than that a proportional absorption of caloric must take place, which will not cause the least increase of temperature. If therefore in fusion and vaporisation an increase of capacity does take place, the phenomena which ought to be produced are precisely those that are actually observed.

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real zero, therefore, may be supposed to be at that number of degrees below the freezing point of water. This calculation has been in some degree confirmed by other experiments. Dr. Crawford, by ascertaining the capacity of water, the capacities of its constituent principles, and the quantity of caloric evolved when they combine, fixes the zero at 1500 below 0 of Fahrenheit; and Mr Gadolin, by observing the changes of temperature resulting from the solution of muriat of soda in water, or from the combination of sulphuric acid and water, and comparing them with the changes that ought to take place from the differences in the capacities produced, states it at 1400. These results, considering the errors to which such experiments are subject, must be regarded as agreeing nearly with each other. The experiments, however, of Lavoisier and Laplace afford results entirely different from these, and even from each other; and the errors to which such experiments are unavoidably liable render every conclusion on this question extremely doubtful,

From the diversity of opinions among chemists respecting the state in which caloric exists in bodies, several forms of expression have been introduced, which it is proper to notice.

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reserve, into the antiphlogistic doctrine, and came at length to be considered as nearly a demonstrated truth.

The opinion of Bacon has, however, been lately revived, and is supported by arguments so forcible, that the question respecting the nature of caloric is at present more than ever a subject of dispute.

The facts which have led to the revival of this opinion are the same with those which induced Bacon to advance it,—the various cases of augmentation of temperature produced by impulse, friction, or whatever is capable of exciting motion of the particles of any mass of matter. On the supposition of the materiality of caloric, this was explained, by supposing that the caloric present was expelled by the repeated impulse arising from the friction, or percussion, forcing the particles nearer to each other. Count Rumford and Mr. Davy, observing these facts with more care, and varying them by experiment, have shewn, however, that caloric continues to be extricated from a body subjected to friction, so long as the friction is kept up, and the texture or form of the body is not destroyed; and have hence concluded, that
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the phenomena are inexplicable on the supposition of caloric being matter. Count Rumford, speaking from his experiments, observes, "that any thing which any insulated body, or system of bodies, can continue to furnish *without limitation*, cannot be a material substance: and it appears to me," he adds "to be extremely difficult, if not impossible, to form any distinct idea of any thing capable of being excited and communicated, in the manner the heat was excited and communicated in these experiments, except it be motion." *

From these investigations it has been concluded, that the phenomena which have been referred to the operation of a peculiar calorific matter, depend entirely on a vibratory motion of the particles of bodies: according as this is more or less intense, a higher or lower temperature will be produced; and as it predominates over, is nearly equal, or inferior, to the attraction of cohesion, bodies will exist in the gaseous, fluid, or solid state: different bodies will be susceptible of it in different degrees, and will receive, or communicate it with

* Rumford's Essays, Vol. II.

with different degrees of celerity : and from the generation, communication, or abstraction of this repulsive motion under these laws, all the phenomena ascribed to caloric are explained. *

The explanation, however, will be found very unsatisfactory. By friction, or any other species of mechanical motion, vibration of the particles of bodies will indeed be induced ; but can the existence of this vibration explain the most important effects of caloric ? Does it account for the most general effect, expansion, or for the production of the fluid and aeriform states ? Vibration is merely the oscillatory motion of the particles of bodies,---that state in which they approach to and recede from each other. How can such a state enlarge the volume of a body to any moderate extent, much more to 1600 or 1800 times its bulk, as happens in many cases, where a solid is converted into vapour ? However violent the vibration may be, it is not easy to perceive how it can induce a permanent repulsion of the particles. If, to explain the phenomena, it is assumed, that the cause of heat is not simple vibration,

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* Davy's Essay in Dr. Beddoes's Medical Contributions.

tion, but a peculiar species of repulsive motion, it becomes necessary to point out the kind of motion ; since, if this is not done, it is not accounting for the phenomena, but only stating the general fact in other terms, and saying, that a repulsion is established between the particles. And were the kind of motion pointed out, it would still be necessary to shew how it was generated by friction ; which, supposing it to be different from vibration, it might be as difficult to do as to explain the rise of temperature from that cause, on the hypothesis of the materiality of caloric. In ascribing temperature, therefore, to mere motion, we have either an opinion, which, though precise, is not sufficient to account for the phenomena, or one which is so vague, that it can be scarcely made the subject of reasoning.

We find also, that the laws of the propagation of caloric are inconsistent with the supposition of its being motion. Were this supposition just, it ought to be propagated instantaneously through an elastic body, while, like a fluid, we find it passes with considerable slowness. It ought also to be capable of passing through fluids and airs, which the experiments of Count Rumford shew that it is not. Neither is the difference in the
quantity

quantity of it contained in bodies satisfactorily explained : for, were it mere motion, it ought to be proportioned to their temperatures and quantities of matter.

On the opposite *hypothesis*, that of a subtle fluid, whose particles are mutually repellent, the phenomena are easily accounted for. The introduction of such a fluid must cause expansion, which, carried to a certain extent, will produce fluidity or vaporisation. This fluid may be capable of being communicated from one body to another ; and from its peculiar relations to each, it may be communicated with different velocities, and may act upon them unequally, so as in equal quantities to produce unequal effects. It is the satisfactory explanation which this hypothesis affords of the phenomena, that has always led to its general adoption.

There are even facts which tend to prove the existence of such a caloric matter, and which are scarcely capable of being explained on the supposition of caloric being motion : such are the radiation of caloric, its passing through a vacuum, and its disposition to ascend, as proved by the experiments of Pictet.

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So far the one hypothesis is much superior to the other. There remains only the difficulty of explaining how caloric, supposing it to be matter, can be produced by friction. In strict reasoning, this difficulty does not warrant the conclusion, that no such matter exists, and the argument, such as it is, is perhaps fully counterbalanced by the difficulties attending that opinion, and the facts that may be urged in favour of the other.

It is also perhaps possible to conceive how the caloric, supposing it to be matter, is excited by friction. The phenomena of electricity furnish a case somewhat analogous; and if we had it not in our power, from the distinction of *conductors* and *non-conductors* of the electric fluid, to trace the source whence it is derived when excited by friction, they would apparently exhibit the impossibility of a finite body furnishing an unlimited quantity of a certain power. May not caloric be excited in a similar manner? When a body is put into a state of vibration, the caloric interposed between its particles, must, in their approximation, be forced out; and it is possible that in the alternating retrocession, the body may be disposed to take caloric from the matter with which it is in contact, rather than again to absorb what it had given

given out. Such a supposition, which, from the consideration of the excitation of the electric fluid, is not improbable, would be fully sufficient to account for the production of caloric by friction; for it would not be difficult to shew, that the arguments used by Count Rumford and Mr Davy, to prove that caloric cannot be communicated from the matter in contact with the body to which the friction is applied, are not conclusive. It does not follow, but that that matter might conduct caloric to the body, though it might at the same time be receiving a portion of the caloric, which the friction renders sensible; neither is it a necessary consequence, that the temperature of the matter thus conducting caloric should be considerably reduced.

If after all we should be obliged to admit, that the motion is more directly the cause of the rise of temperature than this supposition allows, the facts that have been stated still render the opinion, that the mere motion itself constitutes heat, improbable. And when the opposite facts which appear to prove the existence of a calorific matter are considered, we should perhaps be compelled to admit, that if the phenomena of caloric are not owing to the mere
presence

presence of a subtle fluid, neither are they to the vibration of every kind of matter indifferently, but rather to the combination of these causes, to vibrations excited in a peculiar matter, capable of penetrating all bodies; augmentation of temperature being produced either by the communication of a larger portion of this fluid, or by the motion of its particles being rendered more violent. This hypothesis, however, which is similar to the notion entertained by the earlier chemists of the nature of fire, is much less simple, and is perhaps unnecessary.

It has been endeavoured to determine the nature of caloric, by ascertaining whether it possesses weight; but the experiments that have been made with this view have afforded very different results. Some chemists supposed that a body when heated weighed rather more than it did at a low temperature; others concluded from their experiments that it weighed less. Lavoisier, in performing these experiments with his usual accuracy, could observe no difference of weight in the same mass of matter at a low and at a high temperature; and more lately, Count Rumford drew a similar conclusion, from experiments performed with the greatest care.

OF THE MEANS BY WHICH VARIATIONS OF TEMPERATURE ARE PRODUCED.

As caloric has a tendency to diffuse itself over matter, till an equilibrium of temperature is established, it is evident that, were no foreign cause to disturb this tendency, such an equilibrium would at length be formed. Causes, however, are constantly operating, by which it is counteracted; and those variations of temperature necessary for the operations of nature are produced.

Of these causes, the principal is the heating action of the solar rays, modified, however, by others of less powerful operation. The extreme of heat which it might induce, is obviated by the absorption of caloric, which, when the temperature of the earth is high, must take place from the rarefaction of the lower stratum of the atmosphere, and the evaporation of moisture; and the extreme of cold is moderated by the quantity of caloric set loose by the condensation of vapour, and the congelation of water. The temperature
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of the earth is thus always kept within a moderate range.

In the operations of art, greater variations of temperature are requisite. The production of heat is obtained by the concentration of the solar rays, by the electric spark, and by combustion. The last is the mean most generally employed, and, with particular management, is capable of exciting a degree of heat more uniform and lasting, and nearly as intense as that from any other source. The heat produced by other causes of chemical action, or that generated by mechanical motion, can scarcely be applied to any useful purpose.

It is sometimes necessary to effect a reduction of temperature. This may be done by the evaporation of certain volatile fluids, as ether or alcohol; the cold thus produced being sufficient to reduce the thermometer many degrees. The production of cold, however, from some chemical combinations, is much more intense. A mixture of snow and sea salt in equal proportions is capable of reducing temperature to 6° below 0 of Fahrenheit: and there are other saline mixtures capable of producing a far greater degree of cold.

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These form what are termed Freezing Mixtures. The reduction of temperature which they produce is owing to an augmentation of capacity resulting from their mutual action, and in general arising from the liquefaction of the solid salts, or of the water of crystallization which they contain.

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CHAP. IV.

OF LIGHT, AND THE ELECTRIC FLUID.

LIGHT, and the Electric fluid, are chemical agents, analogous in several respects to caloric. Like it, they are too subtle to be obtained in distinct states of existence, or to be traced otherwise than by their effects; and if they exist in bodies in a state of combination, we have it not in our power to separate them, so as to obtain the substances with which they are combined. We can, therefore, only consider their chemical effects, without attempting to describe systematically the combinations into which they enter: and under this view of the subject, as well as from their analogy with caloric, they may be considered in this part of our arrangement.

OF LIGHT.

THE materiality of Light is proved by a number of its properties. Its motion, though inconceivably rapid, is progressive; it may be stopt, or the direction of its motion may be changed; it may be condensed into a smaller, or dispersed over a larger space; and it is inflected when passing near to a body, which proves that it is subject to the attraction of gravitation. It likewise exerts peculiar chemical attractions; and perhaps, next to oxygen, is the most extensive in its influence of any of the chemical agents. These two bodies, light and oxygen, seem designed as antagonists; the combination of oxygen with any body being generally attended with the separation of light, either in a sensible form, or in a state of new combination; while oxygen is scarcely ever extricated without the agency of light.

Light is usually regarded as a substance, or emanation of particles of inconceivable rarity, projected in right lines from the sun, and from all luminous bodies, and moving with extreme velocity.

city. Some have supposed that the phenomena of light rather depend on vibrations, excited in an extremely elastic and rare fluid, diffused through space ; but the former opinion accords more completely with the phenomena, and is more generally received.

Light is not a homogeneous substance, but is composed of particles of various magnitudes, separable from each other. These, when separate, excite the sensations of various colours, and produce different chemical effects. It is separated by the prism into seven rays, red, orange, yellow, green, blue, indigo, and violet. These have different degrees of refrangibility ; the red being the least, the violet the most refrangible.

Light is very differently affected by different bodies. It passes through some with facility ; by others it is reflected from the surface ; some reflect only one set of particles, the red, green, or any of the others, which gives rise to the different colours that bodies exhibit : and there are, lastly, some in which the light is entirely extinguished.

Light

Light can also form a more intimate union with bodies, of which there are different degrees. In many cases it appears to be absorbed, but produces no change in the sensible qualities of the body, and is again gradually given out. In others, it produces alterations of temperature and of composition, or acts as an important chemical power.

The first of these cases constitutes what is termed Phosphorescence, or that property by which certain substances, after being exposed to the sun's rays, appear luminous when removed to a dark place, and continue to emit light for a certain time. It is possessed by many substances, both mineral and vegetable; in general, in the highest degree by those which are white. They are termed Solar Phosphori. Artificial solar phosphori may be prepared much more powerful than the natural: such is the Bolognian phosphorus, which is a sulphat, or rather a sulphuret of Barytes; Baldwin's, which is a nitrat of lime; and Canton's, which is a sulphuret of lime. Some of these phosphori do not emit the white light, but exhibit the prismatic colours.

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The phosphorescent property in all these bodies appear to be the same, differing only in degree. Some require to be exposed to the solar rays, and even to the rays concentrated by a lens, to render them luminous; others acquire the luminous property by exposing them to clear day light for one or two minutes; and some can be illuminated even by the light of a candle, or by an electrical discharge. After the luminous property is acquired by the due exposure to light, it is rendered more vivid by raising the temperature, but it ceases proportionally sooner. By raising the temperature still farther, it may be revived.

These facts, and the general phenomena of phosphorescence, evidently suggest the opinion; that the phosphorescent body when exposed to the light absorbs part of it, different bodies absorbing different quantities; that this light is again gradually emitted, and that its expulsion is promoted by the agency of caloric. This is rendered doubtful, however, by the facts, that when light is transmitted to the phosphorescent body through a coloured glass, or when any of the prismatic rays is thrown upon it, it still continues to emit its usual light. The luminous appearance of these
substances

substances is entirely independent of any action of the air.

There is another class of phosphorescent bodies which become luminous when heated, independent of any previous exposure to light, but the appearance of the light continues only a very short time, and becomes much fainter each time it is excited. In some of them the light is coloured, in others it is white. A similar light is obtained from them by attrition. The native fluat of lime, quartz, and the gems, are the principal phosphori of this kind.

The last species of phosphorescence is that of animal matter. Marine animals are remarkable for this property ; it has also been observed in the flesh of some quadrupeds, and several insects appear very luminous in the dark. The light from rotten wood appears to be of a similar kind. This light was supposed to be emitted in consequence of incipient putrefaction, and some even ascribed it to a species of gas discharged during that process. But Dr. Hulme has shewn, that so far from this being the case, it ceases whenever putrefaction begins. Its emission is not accompanied with any sensible extrication of caloric ; it is promoted by a moderate heat. The luminous matter

ter on which it depends, Dr. Hulme found, could be separated from these substances, by several saline solutions, which then acquired the property of emitting light. It is extinguished by pure water, by acid or alkaline solutions.

The chemical effects of light upon bodies are next to be noticed. These may perhaps be entirely referred to its power of separating oxygen from its combinations. Hence it is capable of reducing the metallic oxyds, and of decomposing the nitric and oxygenated muriatic acids, by expelling the oxygen which they contain. Its influence on vegetation depends on the same operation. Plants which are secluded from the light are insipid, colourless, feeble, and irritable, and during their growth emit only carbonic acid: but when exposed to the solar rays they become vigorous, acquire a green colour, and become more fragrant, pungent, and inflammable. During this exposure, they emit oxygen gas in abundance; apparently from the decomposition effected by the chemical agency of light, of the water and carbonic acid which they absorb. Nor are animals exempted from the influence of light; but suffer changes from it somewhat similar to those of vegetables.

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The experiments of Sennebier have proved, that the different rays of light produce the same chemical effects in very different degrees. The muriat of silver is blackened by light: he found, that the shade produced by the violet rays in 15 seconds required, for its production the action of the indigo for 23; of the blue, 29; of the green, 37; of the yellow, 5½ minutes; the orange, 12; and the red, not less than 20 minutes.

The last general effect to be observed in the chemical history of light, is its power of heating bodies, or raising their temperature.

The heat excited in different bodies by the solar rays is very different. Those which are transparent suffer them to pass with scarcely any interruption, and have, therefore, their temperature little raised. White bodies, reflecting the light from their surface, are less heated than those which are coloured, in which more of the light is retained: and from the experiments of Franklin, it appears that the darker coloured any body is, the more it is heated by the solar light. The different rays of light have likewise different heating powers; the heating power, according to the experiments of Herschel, following inversely the order

der of their refrangibility,---the least refrangible possessing it in the greatest degree. This last fact, compared with the experiments of Sennebier, serves to establish clearly the peculiar chemical properties of light. Count Rumford had supposed, that the effect of light in de-oxydating bodies might be owing entirely to its exciting a very high temperature in the point on which it strikes; an opinion at first view not improbable. But these experiments prove, that the rays most powerful in exciting temperature, are those which possess the least power of producing these chemical effects.

It has always been an object of investigation among chemists, In what manner does light act in heating bodies? or, What is the nature of that intimate connection which appears to subsist between light and caloric? The connection seems so intimate, that many were led to regard them as essentially the same, or as modifications of the same kind of matter, differing from each other principally in their state of motion. Others supposed that light was a peculiar matter, combined with a large portion of caloric; while not a few ascribed the heating property of the rays of light to their power of exciting vibrations in the matter on which they strike.

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The late valuable experiments of Dr. Herschel, perhaps render the discussion of these opinions unnecessary. He has shewn, that there exists in the solar rays, and also in the light thrown from luminous bodies, rays which are invisible, or incapable of exciting vision, but which are powerful in exciting heat. These invisible rays are propagated in right lines with extreme velocity, and are capable of reflection and refraction. Being less refrangible than the visible rays, they are partly separated from them by the prism, and are thrown principally towards one extremity of the prismatic spectrum; and accordingly at that point the heating power is greatest. The solar rays consist, therefore, of two kinds of matter,---of pure light, and of radiant caloric: their heating power seems to depend on the latter, while it is in the former that their peculiar chemical properties reside.

Light then may be considered as a peculiar substance or matter, capable of entering into combination with other bodies, and actually existing in them as a chemical constituent principle. Hence we explain its extrication in many cases of chemical action, and the important chemical changes it produces in many bodies. Light at
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the same time, whether derived from the sun, or extricated from bodies, is accompanied with caloric matter in a similar state of motion; and on the presence of this matter does the power which light has of raising the temperature of bodies depend. These two kinds of matter are essentially different; they are distinguished not only by the different sensations they excite, but by the possession of very different chemical properties: caloric in a state of projectile motion is still very different from light, and light in quiescence has properties entirely dissimilar from those of caloric.

ELECTRIC FLUID.

THE phenomena of electricity are supposed to depend on a certain fluid, distinguished by particular properties. It is present in the earth, and in all bodies in certain quantities, it can pass along the surfaces of some with facility, while there are others which are nearly incapable of conducting it. It is accumulated by friction on the surface of bodies of the latter kind, and may be carried off by the application of any of those which are capable of affording it a ready passage. Bodies, therefore, may either be deprived of a
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large share of the portion of this fluid which they naturally contain, or a greater quantity than natural may be accumulated in them. On these principles the general phenomena of electricity are explained. It is foreign to the object of this work to consider it otherwise than as a chemical power.

When electricity is transmitted in considerable quantity through bodies, it raises their temperature ; and its heating power is so great, that it is able to melt even those metals that are most difficult of fusion. Its force in this respect is found to depend on the proportion between the quantity of fluid transmitted, and the volume of the body through which it is sent ; and it is therefore probable, that the heat produced depends on the force of its mechanical impulse. Van Marum found, that the fusibility of the different metals by the electric fluid, is different from the order of their fusibilities, by the direct application of caloric.

The electrical discharge, from its power of suddenly raising temperature to an intense degree, is a powerful mean of promoting chemical combination. When transmitted through metallic wires,

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in contact with atmospheric air, their surface is oxydated ; even gold and silver suffer from it this change, though nearly incapable of oxydation from the greatest heat which any furnace can excite. The electric spark is likewise the most effectual mean of effecting the combination of several of the gases, which, when merely mixed together, do not unite. It is equally capable, in many cases, of effecting decomposition, apparently from its power of exciting a high temperature in the point at which it is received.

The electric fluid partakes likewise of the nature of *light*, as is evident from the spark, and luminous train which it may be made to exhibit, and not less evidently from its chemical action : we find it is capable of decomposing several compounds, and resolving them into their constituent principles, one or both of which principles contain light as a constituent part ; and the light necessary for their constitution cannot in these decompositions be derived from any other source than the electric fluid.

Lately a particular mode of exciting the electric fluid, and directing its action, so as to obtain the most important and singular chemical effects,
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has been discovered. Volta, in prosecuting his researches on the phenomena of Galvanism, or animal electricity, found that by the mere contact of conducting substances of different kinds, phenomena similar to those of electricity were produced. The apparatus he constructed consists of plates of metal, of two different kinds, as of zinc and silver, or zinc and copper, placed alternately above each other, a piece of pasteboard, or any other soft porous substance, moistened with water, or with certain saline solutions, being interposed between each pair. A column or pile of this kind, consisting of thirty, fifty, or more pieces of each metal, excites electricity so strongly, that when the top and bottom pieces are touched at the same time by the fingers moistened, a sensation is communicated, somewhat similar to that of the electric shock, and a luminous point or spark can also be produced. The operation of this apparatus in effecting chemical decomposition is not less striking. When a metallic wire from the plate at the top of the column, and another from that at the bottom, are inserted in a tube, containing water, alcohol, ammonia, or any compound fluid, one of the principles of which is a body which exists naturally in the gaseous form, a decomposition immediately commences, and continues to go

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on, as long as the apparatus retains its power not much impaired.

There can be little doubt that the agent concerned in the production of these phenomena is the electric fluid. This is proved by the sensation it excites, by the spark which it gives, by its passing easily through conductors of electricity, being stopt in its course by non-conductors, and by its affecting the electrometer when in a powerful state. It has even been ascertained, that the electricity discharged by the wires connected with the top and bottom of the column, is in different states, that from the one being positive; that the other negative.

How the electric fluid is excited, or called into action, by the mere contact of conducting substances which constitutes this apparatus, is not easily explained. From the facts already ascertained, it seems probable, that this peculiar disposition has little or no share in its production; that the utility of a series of electrical conductors is only to collect and conduct the power when excited; but that its excitation depends on a very different cause, the chemical action going on in the pile. Although friction be the principal and
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indeed the most powerful mean by which electricity is excited, it is not the sole one: it is likewise rendered active by heating and cooling bodies, by fusion, and by vaporisation. It is therefore probable that it may also be excited by chemical action, and thus give rise to the phenomena of the pile of Volta, and of Galvanism in general.--- That a chemical action is exerted among the substances composing the pile, is indeed clearly proved, since one of the metals is always oxydated, and the saline solution employed to moisten the pasteboard is decomposed: and that this action is intimately connected with the excitation of the electrical energy is established by numerous experiments. The power of the apparatus ceases when it is placed in the exhausted receiver of the air pump, or in a vessel filled with azotic or hydrogen gases. It is more powerful in oxygen gas than in atmospheric air, and in either the oxygen is consumed; and its powers are much increased when the water in contact with the metal holds in solution, oxygen, nitrous gas, diluted nitric or muriatic acid, or any substance which either affords oxygen with facility, or promotes the oxydation of the metal. The power of the galvanic series or column seems indeed to be proportional to the oxydation of the metal which com-

poses it, and hence it may with much probability be concluded, that it is to this chemical action, that the excitation of the galvanic influence is owing.

The mode in which this peculiar power operates in producing the changes which arise from its action is extremely obscure. It evidently differs in certain respects from the operation of the common electrical discharge, and the phenomena it produces are scarcely analogous to any other kind of chemical action. When water, for example, is decomposed by it, it is not by one of the metals attracting the oxygen of the water and letting loose the hydrogen; neither are the principles of the water separated at the point at which it acts, and the two gases disengaged together: but from the extremity of the one wire pure oxygen is extricated, and pure hydrogen from that of the other; and this, although the wires be at a distance from each other, and even placed in separate tubes. Similar anomalous appearances are observed in the decomposition of other fluids, and they are such as, in the present state of our knowledge of the nature and powers of this agent, cannot be satisfactorily explained.

PART II.

OF

THE SIMPLE SUBSTANCES, AND THEIR BINARY COMPOUNDS.

HAVING considered these general powers, which, by their action on matter, give rise to the principal phenomena of Chemistry, we have next to investigate the chemical properties and actions of the individual substances on which they operate. In this investigation we follow the division of bodies into Simple and Compound, as the one best adapted to the nature of the science.

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In the language of modern chemistry, the term Simple, or Elementary, has a signification different from that attached to it by the ancient philosophers. They understood it as expressing substances *essentially* simple and indestructible, which, by modifications of form, or combinations with each other, form the different substances which compose the material world. By modern chemists it is understood in a different sense. As the object of their science is to investigate the composition of bodies, or separate them into their constituent principles, they must necessarily in their operations arrive at certain substances, beyond which the analysis cannot be carried. Such substances are termed Simple. The term implies not their absolute simplicity; for it is very possible, and even probable, that they may be compounds. But it is assumed as a general principle, that every substance is to be regarded as simple which has not been decomposed; and therefore every kind of matter obtained by chemical analysis is ranked as such, which cannot be resolved into two or more constituent parts.

There is some limitation, however, to this principle. There are several substances which chem-
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ists have not hitherto been able to decompose, but which they have the strongest reason from analogy to believe are compounds. The class of chemical agents, for example, termed Acids, consists of substances, the greater number of which are proved not only to be compounds, but to contain one common acidifying principle. There are three of them, however, which have resisted every method of analysis that has been applied: but the analogy between these and the other individuals of the same class, is so direct and unexceptionable, that no chemist at present hesitates in considering them as compounds. A similar analogy exists in another class of chemical agents, the Alkalis. One of them has been proved to be compound; there are other two which have not been analysed, but which the same analogy leads us to regard as compounds; and there are even facts which favour this conclusion. It would, therefore, be a very unnecessary adherence to rigid systematic arrangement, were any of these substances, either acids or alkalis, to be considered as simple, and separated from those with which they have a natural connection.

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With these exceptions, the substances which have not been decomposed are regarded as simple. The number of them whose materiality and distinct existence have been established, and whose chemical characters we can fix with certainty and discrimination, amounts to nearly forty. They may be arranged under the following orders: 1st, Simple substances naturally existing in the gaseous form, comprehending Oxygen, Hydrogen, and Azot; 2dly, Simple inflammable substances, comprehending Carbon, Sulphur, and Phosphorus; 3dly, the Metals; and, 4thly, the Earths.

The substances comprised under the first order, the Simple Gases, are the most important of the chemical agents, as they enter as constituent principles into by far the greater number of the productions of nature. They, therefore, properly occupy the first place in any chemical arrangement.

After they have been described, it will be convenient to consider the combinations into which they enter with each other, and the products to which these give rise, before proceeding to the enumeration

enumeration of the other simple substances. Under the combination of hydrogen and azot, the class of chemical agents termed Alkalis, may first be considered, as we thus obtain the greatest advantages of arrangement, these substances combining with many of the remaining simple bodies and their binary compounds, and forming important compounds. The general phenomena attending the combinations of oxygen, and the generic characters of the products of oxygenation, may next be noticed, and then the peculiar combinations of oxygen with the other two simple gases may be considered.

We next proceed to the second order, the Simple Inflammables, noticing their properties, their combinations with the simple gases, with each other, and with the several compounds which have already been described, and likewise the properties of the new compounds which result from these combinations. After the same manner, the remaining orders of Metals and Earths may be considered.

There remains an extensive class of compounds, those which are the products of organisation; in
other

other words, the Vegetable and Animal products. These are with propriety reserved for separate consideration, as they possess chemical characters by which they are clearly distinguished from the preceding compounds.

Under these divisions may be arranged every substance, either existing in nature or produced by art, which it belongs to chemistry to consider.

CHAP. I.

CHAP. I.

SIMPLE GASES.

THE term *Air* or *Gas* is applied to substances which are so rare as to be invisible, but whose weight we can estimate, which are compressible, and permanently elastic. The atmosphere, or that mass of invisible elastic fluid which surrounds the globe, affords a familiar example of a body existing in this form, and there are many others, each being distinguished by the possession of peculiar chemical properties.

It has already been observed that the aeriform state depends upon the agency of caloric. When a solid body is heated to a certain extent, it becomes fluid, and the fluid by a further addition of caloric, has its particles separated to such distances, that the attraction of cohesion is overcome, an elastic or repulsive power is acquired, the fluid becomes so rare as to be invisible, and thus passes into the state of vapour or gas. If it requires a high temperature to cause it to pass into the aeri-

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form state, it is condensed by a moderate degree of pressure or cold ; if it assumes this state at a very low temperature, it is permanently elastic, or retains its aerial form at the lowest natural temperature. Substances existing in the former state are termed Vapours ; to those which are permanently elastic, the term Air, or Gas, is particularly applied. The distinction between them is only relative, and arises solely from the difference of temperature at which they are formed.

A Gas is therefore merely a solid body, between the particles of which repulsion is established by the large quantity of caloric which it contains. In the modern nomenclature, the name of every substance existing in this form is derived from its solid base, and the term Gas is used to denote its existence in this state. Thus *Oxygen* is the name of the solid base or gravitating matter of one of these bodies, which in its aerial form, is termed Oxygen Gas. This solid base cannot be obtained pure, but no chemist doubts of its existence, or that we should obtain it, could we abstract from the gas, caloric to a sufficient degree, and it, as well as the solid matter of the other gases, exists in a solid state in many of the combinations into which they enter.

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In examining the different gases, besides the general properties of rarity, compressibility, and weight, they are found to be endowed with peculiar properties by which each is distinguished. Atmospheric air, for example, is characterised by its capability of supporting combustion and animal life, by its sparing solubility in water, and its dissolving a portion of that fluid. It is easy to conceive that other substances may exist in the same form, possessing different properties; and that this is the case, the chemist discovers in examining the elastic fluids produced in his operations. He finds one in which combustion is much more vivid than in atmospheric air; another, incapable of supporting combustion, but itself inflammable; a third, which possesses neither of these properties; and others which are absorbed by water, and which possess various properties by which they are distinguished from every other.

In examining the gases, with regard to their composition, we find that the greater number of them are compound bodies. There are only three of them which are simple, Oxygen, Azot, and Hydrogen, and these form the first order of simple substances which we have to consider.

SECT. I. — — OXYGEN GAS,

THIS gas, named Oxygen, from its property of producing acids, formerly known by the names of Vital air, Fire air, Dephlogisticated air, was discovered nearly about the same time by Scheele and Priestley. It exists no where pure in nature, but abundantly in combination with other bodies; and it is from some of these combinations, into which it enters as a constituent part, that it is obtained. If a quantity of the native mineral production, termed the black oxyd of Manganese, be exposed in an iron vessel to a red heat, a large quantity of oxygen is separated from it, and passes off in the state of gas: or if any quantity of it be mixed with two parts and a half of sulphuric acid, in a glass retort, the oxygen is expelled by the application of the moderate heat of a lamp. It is also obtained from many other substances, of which it is a component part, by the application of heat, as from nitre, red lead, or red oxyd of mercury; and it is yielded in considerable quantity by growing vegetables exposed to the action of light.

Oxygen

Oxygen gas is destitute of smell or taste ; is rather heavier than atmospheric air ; the specific gravity of the one being to that of the other as 1103 to 1000. It is absorbed by water, but in very inconsiderable quantity ; and it also always contains a portion of that fluid.

The peculiar properties by which oxygen gas is distinguished are those of supporting combustion and animal life ; combustion is much more vivid in it than in atmospheric air, and an animal lives longer in a certain volume of the one than in an equal quantity of the other. Oxygen is indeed the only gas capable of supporting either process, atmospheric air, or any other gas, doing so merely from the quantity of oxygen it contains.

Oxygen has a tendency to combination, more extensive, perhaps, than any other simple substance. It combines with every combustible body, and with all the metals ; it forms the fourth part of atmospheric air ; and it is a principal ingredient in by far the greater number of vegetable and animal substances.

Sett. II. — — AZOTIC GAS.

ATMOSPHERIC Air contains about one-fourth of its volume of oxygen ; the remaining three-fourths consist of a peculiar gas termed Azotic, in the language of the new nomenclature, from its being incapable of supporting animal life. Nitrogen, a name given to it by Chaptal, is more unexceptionable, but the other is established by common usage. It is the Phlogisticated air of Priestley, the Foul air of Scheele.

This gas is obtained by exposing atmospheric air to substances capable of absorbing the oxygen it contains. If a quantity of it in a jar be thus exposed to a solution of the substance termed Sulphuret of Potash, the volume of the air begins to diminish from the absorption of the oxygen, and after a certain time nothing remains but the azotic gas. It is also obtained by burning phosphorus, or any of the metals in atmospheric air, these attracting the oxygen ; and as the compounds which they form exist in the solid form, the azot remains pure in the state of gas.

This

This gas is not possessed of any remarkable property capable of characterizing it; it is principally distinguished by certain negative qualities,—by its being incapable of supporting combustion and animal life, by being unflammable, and by not being absorbed by water, or at least in very inconsiderable quantity. The peculiar compounds which it forms with other bodies, afford also decisive proof of its existence as a substance distinct from every other.

Azotic gas is rather lighter than atmospheric air, its specific gravity being as 985 to 1000. It is destitute of taste and smell.

Azot enters as an ingredient into many compounds. It constitutes three-fourths of the atmosphere: it combines with hydrogen and phosphorus, is a component part of all animal substances, and communicates to them their most distinctive characters: It likewise exists in the products of several vegetables.

Sect.

SECT. III. — —, HYDROGEN GAS.

THIS Gas was discovered by Mr. Cavendish, and named Inflammable Air, from its inflammability: in the new nomenclature it is termed Hydrogen, as being the basis of water. It may be said to exist in nature, as it is often collected in the roofs of caverns and mines, being known to miners by the name of Fire Damp; and it likewise probably exists nearly pure in the higher regions of the atmosphere. For chemical purposes, however, it is always obtained by artificial processes. It is a component part of water, that fluid being a compound of it with oxygen; when, therefore, water is decomposed by any substance capable of attracting its oxygen, hydrogen gas is disengaged. Thus if water be passed over iron or zinc filings heated to ignition, such a decomposition takes place, and hydrogen is produced in abundance. Or, what is an easier process, if $2\frac{1}{2}$ parts of water, to which one part of sulphuric acid has been added, be poured upon one part of either of these metals, an effervescence is immediately produced from the copious extrication of hydrogen; the acid enabling

bling the metal to decompose the water even at a low temperature.

Hydrogen gas is peculiarly distinguished by its great levity and inflammability. It is the lightest substance whose weight we are able to estimate. When in its purest state, and free from moisture, it is about 13 times lighter than atmospheric air. It burns rapidly when kindled in contact with atmospheric air, and it explodes instantaneously when it is previously intimately mixed with a portion of that air or of oxygen gas. It is incapable of supporting combustion or animal life, though it is not immediately deleterious, as the greater number of the unrespirable gases are. It is not injurious to growing vegetables.

Water absorbs a small portion, about 1-13th of its bulk, of hydrogen, and the gas itself always contains a considerable quantity of that fluid.--- This water adds both to its bulk and specific gravity. When saturated with it, it occupies about 1-8th more space than when free from it; and it is only 10, instead of 13 times lighter than atmospheric air.

its presence that several of the phenomena of *Meteorology* depend.

The other fluid, however, that which composes the inferior part of the atmosphere, is that only which we have it in our power to examine; and it is to this mixture of oxygen and azot that the term Atmospheric air is exclusively applied. Its composition has been found nearly uniform at the greatest heights which have been reached.

We are indebted to Scheele for the discovery of the composition of atmospheric air. He observed, that in processes in which it was exposed to the action of certain substances, it suffered a diminution of volume; and that, at the same time, it was rendered incapable of supporting combustion, and, when inspired, proved speedily fatal to life. He had previously made the discovery of oxygen gas, and observed its properties of enabling inflammable bodies to burn with great splendour, and of supporting animal life much longer than atmospheric air. When he found, therefore, that in these processes by which atmospheric air is diminished, the quantity which remains is incapable of sustaining combustion or animal life, he concluded that this change was owing to the abstraction

fraction of oxygen from it, and that it is a compound of this gas, and of the remaining unrespirable gas, which he termed Foul or Corrupted air, and which is the azotic gas of modern chemists. This conclusion he confirmed, by adding to this gas a fourth part of oxygen; when a compound, having all the properties of atmospheric air, was formed. Lavoisier soon after made the same discovery, and established it by a variety of experiments. He proved it in particular more clearly by shewing, that in those processes in which atmospheric air suffers this diminution of volume and change of properties, oxygen is absorbed by the body by which the change is effected, and can frequently be recovered from it in a pure state.

It is still a subject of dispute among chemists, whether the oxygen and azot existing in the atmosphere are in a state of chemical combination, or of mere mechanical mixture. That they are combined, is supposed to be proved by their not separating in the atmosphere, or even when kept free from agitation, though of different specific gravities. The difference, however, is very inconsiderable: there are various causes constantly acting on the whole mass, and agitating the different

rent parts; which must in a considerable degree counteract the tendency to separation; and after all, it seems certain that such a separation does take place. It has been ascertained by Saussure and Van Humboldt, authorities on this subject superior to any other, that the air in the higher regions contains less oxygen than it does in the inferior strata; and it is in particular affirmed by the latter philosopher, that this difference is greater than any that is to be found in different places at the surface of the earth. It is evident, that such a separation could not take place, were these gases chemically combined.

It is besides to be remarked, that in the circumstances of the mixture of these airs, or in the properties of the resulting mass, there is nothing to favour the supposition that they enter into combination. They mix together in every proportion, and no new properties are acquired, those of the atmospheric air (that of the specific gravity excepted, according to some chemists,) being merely the mean of those of the oxygen and azotic gases. Yet when placed under certain circumstances, by which the exertion of chemical attraction is promoted, they unite in determinate

terminate proportions, and form compounds possessing properties very different from those of their component parts.

Perhaps that chemical attraction which subsists between the solid bases of these gases, but which, when they are merely mixed together, cannot, from the distance at which their particles are placed by the repulsive power of caloric, bring them into intimate union, may still be so far exerted as to prevent their separation: or they may be retained in mixture by that force of adhesion which, exerted at the surfaces of many bodies, retains them in contact with considerable force. This latter supposition seems to be favoured by the facts which Dr. Priestley observed, that even those gases between which no chemical attraction seems, under any circumstances, to be exerted, do not separate when mixed, though of very different specific gravities. Either of these causes, joined to the inconfutable difference in the specific gravities of oxygen and azot, and assisted by the agitation which the atmospheric mass constantly suffers in all its parts, from winds and currents, from electrical discharges, and from the ascent of the heated air from the surface of the earth, may preserve them mixed in nearly an uniform

niform proportion, without supposing them to be in that state which can properly be termed chemical combination.

The measurement of the quantity of oxygen contained in the atmospheric air, or indeed in any gas in which it is merely mixed, is termed *Eudiometry*; and the instrument by which it is performed, the *Eudiometer*. It consists merely in adding to the air some substance capable of combining with the oxygen; and from the diminution of volume which the air suffers, the quantity of oxygen it contains is determined.

Different substances have been used for this purpose, each in the opinion of some chemists possessing advantages over the others. The watery solution of *sulphuret* of potash, employed by Scheele, completely abstracts the oxygen; but it is slow in its operation, and does not immediately indicate when the process is finished. The dry sulphuret of potash assisted by heat, is liable to the latter objection, and is a method not easily executed. *Hydrogen* mixed in a determinate proportion with the air, and fired by the electric spark, forms the Eudiometer of Volta; but it requires a complicated apparatus, and is liable to error from the hydrogen

hydrogen not being uniform in quality. *Nitrous Gas*, added to any air containing oxygen mixed with it, immediately abstracts it, and shews the quantity by the diminution of volume it occasions; but the result cannot be depended on from the varying quality of the nitrous gas, and from the extent of diminution which it occasions being influenced by various minute circumstances. The slow combustion of *Phosphorus* over water, affords perhaps the best Eudiometer; it entirely abstracts the oxygen, and it indicates when the process is finished, by no longer appearing luminous in the dark, or by the disappearance of a white cloud with which it appears in day-light to be surrounded. It is only necessary to make allowance for an increase of volume in the remaining azot, of one-fortieth part, from part of the phosphorus being dissolved in it, by which its bulk is so far augmented.

Eudiometry is of little utility in ascertaining the purity of air, considered with respect to its salutary or noxious power on life. The air of places the most unhealthy has been found to afford as much oxygen as that of others of the opposite character: the noxious air, in different situations

or seasons, depending not so much on deficiency of oxygen, as on the presence of effluvia, or other impregnations not to be discovered by this test. Sometimes, however, a vitiated state of the atmosphere is pointed out by these means; and the method itself of indicating the quantity of oxygen in any air, is of much use in chemical experiments on the gases.

Besides these two gases of which atmospheric air consists, there is a small portion of another, Carbonic acid, always present in it. The proportion of it is about 1 part in the 100, and it has been found at the greatest heights which have been reached.

Atmospheric air, like the other gases, is transparent, compressible, and permanently elastic: its specific gravity is to that of water as 830 to 1. It is inodorous and insipid, is breathed by animals, is necessary for vegetation, and indispensably requisite for the support of combustion and animal life.

This air is absorbed by water, though in inconsiderable quantity: the greater part of it may be expelled by boiling the water, or by removing
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the atmospheric pressure, by means of the air pump.

Atmospheric air can also dissolve a quantity of water, more or less according to its temperature. Hence a constant evaporation is going on at the surface of the earth, which is again deposited in the form of dew, snow, or rain. This forms what is termed *Spontaneous* Evaporation, a process of the first importance in the economy of nature.

Some philosophers have called in question this solvent power of atmospheric air, with respect to water, and have ascribed spontaneous evaporation to the mere operation of caloric, principally from observing, that even in the exhausted receiver of the air pump, water evaporates at a medium temperature. But it is a very erroneous conclusion, that under the atmospheric pressure it will evaporate at the same temperature. There undoubtedly exists an attraction between air and water, since the latter always contains a portion of the former; the reverse must therefore equally take place; and the exertion of this attraction in spontaneous evaporation, seems clearly proved by the facts, that more water is evaporated in a dense than in a rare atmosphere, and that even ice diminishes

diminishes in weight when placed in air whose temperature is below 32°. All the phenomena of spontaneous evaporation likewise accord with the supposition that it is a case of chemical solution.

The quantity of water dissolved by the atmospheric air, is greater as the temperature is high. Dr. Hutton has supposed, that the solvent power of the air increases in a greater *ratio*, than the temperature is augmented; and from this hypothesis has deduced an ingenious explanation of the production of rain.

It is difficult to obtain air perfectly dry: for this purpose it is necessary to expose it to substances which have a strong attraction to water. Its state with respect to moisture is shewn by the instrument termed the Hygrometer.

Atmospheric air is an important agent in many chemical processes. It is necessary to support combustion, and it is equally indispensable to animal life. It influences the process of crystallization by its pressure, and by its chemical action it slowly effects changes in the greater number of substances which can be exposed to it.

CHAP. II.

COMBINATION OF THE SIMPLE GASES WITH
EACH OTHER.

Sect. I. — AZOT WITH HYDROGEN.

ALKALIS.

THE combination of azot with hydrogen forms a compound termed Ammonia. This is one of *three* substances which, as they possess a number of common properties, have been always arranged together under the name of Alkalis. The remaining two, Potash and Soda, have not been completely analysed: their analogy, however, with ammonia, renders it extremely probable that they are compounds; and it has lately even been supposed that their composition has been discovered; that potash is a compound of lime and hydrogen, and
soda

soda a compound of hydrogen and magnesia. This, however, has not been proved by any conclusive experiments ; but as there is so much probability in the supposition that these substances are compounds, and as they resemble ammonia in so many properties, they may be considered in this part of our work.

The following are the general properties of alkalis. They impress an acrid taste on the tongue ; they inflame and even corrode the skin, and dissolve animal matter ; they change the blue or red colours of vegetables to a green ; they have a strong attraction to water ; they unite with oils or animal fats forming soap ; and they combine with another class of compound bodies termed acids, forming new compounds in which both the acid and alkaline properties are lost.

AMMONIA.

WHEN hydrogen and azotic gases are mixed together, they exert no mutual action, the gaseous form being an effectual obstacle to their union. The composition of ammonia, the compound which results from their combination, was therefore

fore discovered only by its decomposition, and by its production in certain chemical processes in which these gases are concerned. Dr. Priestley observed, that on subjecting ammonia in the state of gas to the action of the electric spark, its volume is increased, it is no longer absorbable by water, and becomes highly inflammable; a similar change he found to be produced in it, by passing it through an ignited earthen tube; and he farther found, that when the ammonia was heated with a metallic oxyd, the metal was deprived of its oxygen, and a gas was produced, possessing all the properties of azot. Scheele likewise observed this last fact, and Bergman hazarded from it the conjecture, that ammonia is a compound of azot and hydrogen, a conjecture which Berthollet confirmed by a variety of experiments in which ammonia was decomposed. It was afterwards established by synthesis, ammonia being formed by presenting the two gases to each other in their nascent state,---in other words, at the moment in which they are disengaged from a chemical combination in which they existed, and before they fully assume the gaseous form. The solution of tin in diluted nitric acid affords an example of this kind; the tin attracts the oxygen of the acid, as well as the oxygen of the water, and the azot of
the

the former and hydrogen of the latter being disengaged, unite and form ammonia.

Dr. Austin from synthetic experiments, states the proportion of azot and hydrogen, as existing in ammonia, at 121 of the former to 32 of the latter. Berthollet, from his analysis of it, states them at 121 to 29, with which the late experiments of Mr Davy nearly agree, these making 100 parts of ammonia to consist of 80 of azot and 20 of hydrogen.

Ammonia is afforded in great quantity by the decomposition of animal substances, by heat, or putrefaction; the azot or hydrogen they contain being disengaged and combining together. It is also yielded by some vegetables.

The production of it from animal substances is the source whence the ammonia, used for chemical purposes, is obtained. It is at first impure, but is freed from the animal matter adhering to it, by combining it with an acid. In this manner the muriat of ammonia, or sal ammoniac, which is used in large quantity in the arts, is prepared; and from this pure ammonia is obtained. One part of this salt, the muriat of ammonia, is mixed with

with two parts of newly flaked lime, in a retort, and a moderate heat applied. The lime attracts the muriatic acid of the muriat of ammonia, and the ammonia is disengaged in the state of gas, which must be received in jars placed over mercury, and filled with that fluid.

Ammonia, when pure, exists in the state of permanent gas; it is the lightest of the gases, hydrogen excepted, its specific gravity being to that of atmospheric air as 600 to 1000: it has a strong pungent smell, and is capable of inflaming the skin. It proves fatal to animal life, when respired pure; is incapable of supporting combustion; but is slightly inflammable, the flame of a candle being enlarged when immersed in it, and when mixed with oxygen gas, it even burns.

Ammoniacal gas has a strong attraction to water, and is rapidly absorbed by it, in very considerable quantity. The solution has the strong pungent smell, and all the qualities of the ammonia, and was formerly considered by chemists as the alkali in its pure state; but Dr. Priestley shewed that it is only a watery solution of it. It is the form, however, under which the ammonia is usually kept and used. It is prepared by mix-

ing five parts of muriat of ammonia with twelve of flaked quick lime, and adding as much water as is sufficient to moisten them. On heat being applied to the retort, the ammoniacal gas is disengaged, and is made to pass through water, placed in a series of receivers, by which it is absorbed. This solution is termed Water of Ammonia, or Liquid Volatile Alkali, from the tendency of the ammonia to pass off from it in the state of gas.

Ammonia exerts no action on the simple gases. Its combinations with other chemical agents are afterwards to be noticed. Its attractions to the acids are inferior to those of the other alkalis.

POTASH.

THIS substance was usually known by the name of Fixed Vegetable Alkali; *fixed*, in contradistinction to ammonia, which was termed Volatile Alkali; and *vegetable*, as being derived principally from the burning of vegetables. In an impure state it forms the potashes of commerce; whence the name *Potash*, received into the new nomenclature, is derived. It would have been preferable, perhaps, to have given it the termination

tion of Potassa, but the other is now established in chemical language.

Potash is obtained by burning vegetables, especially the woody parts. It forms the principal part of the ashes which remain, mixed, however, with several other substances. The soluble matter is freed from the other impurities by solution in water; and this solution, evaporated to dryness, yields the potashes of commerce. These consist of potash combined with carbonic acid, and several neutral salts. A second solution of them is made in water, and the greater part of the neutral salts is separated by crystallization; the carbonic acid is abstracted by quick lime, and a solution of potash remains, which may be evaporated to dryness. This potash, however, is still impure. To obtain it in a state of purity, it is dissolved in alcohol, which leaves the other saline matters mixed with it undissolved, and the solution is evaporated to dryness in a cup of silver or tin.

Potash, thus purified, is a solid substance of a white colour, crystallizable from its saturated solution in alcohol or water; it is extremely caustic, changes the vegetable colours to a green, and has so strong an attraction to water as to
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take it from almost every other substance, and to absorb from the atmosphere, in a very short time, a sufficient quantity to render it fluid. It is fusible at a moderate temperature, but can scarcely be volatilised by the most intense heat. It combines with oils and fats, forming a perfect soap; fused with siliceous earth it forms glass, and with a larger proportion of alkali, a substance soluble in water. It combines with all the acids, and has in general a stronger attraction to them than either of the other alkalis has. It also unites with many other substances, as sulphur, phosphorus, and others, forming combinations afterwards to be noticed. It does not act on any of the simple gases.

The proper analysis of potash, it has been remarked, has not been completely effected; but there are a number of facts which appear to prove its composition. Thus it has been ascertained by experiment, that it is formed in what are termed nitre beds, or collections of the materials from which nitre is formed, though in none of these it could have pre-existed. It is even probable, that in the process by which it is usually obtained, the incineration of vegetables, it is at least partly formed. From facts of an analytic kind, it has lately

ly been concluded, that it is formed of lime and hydrogen, lime having been produced under circumstances where, of all the bodies concerned, none could furnish it but the potash, and this production of lime being always preceded by the combustion and disappearance of hydrogen. Others have inferred from analogy, that azot is the alkaline principle, as it is the principal constituent of ammonia.

S O D A.

Soda, the third alkali, has likewise been termed Fixed Mineral Alkali, as it is more abundant than either of the others in the mineral kingdom. It is found native in the earth or on its surface, combined with carbonic acid ; and it exists in immense quantity in the water of the ocean, common sea salt being a compound of it with muriatic acid. It is obtained principally, however, from the combustion of several marine plants, the saline matter obtained from their ashes containing this alkali combined with carbonic acid. The pure soda is obtained by the same process as that employed for the purification of potash.

Soda

Soda when perfectly purified is in a solid white mass, which is capable of crystallization from its solution in alcohol or water : it is acrid and corrosive, has a strong attraction for water, is fusible in a moderate temperature, melts with filiceous earth forming glass; unites with oils, and combines with all the acids. Its properties are so very similar to those of potash, that in their pure state it is scarcely possible to discriminate between them. They are easily distinguished, however, by their orders of attraction, and by the compounds which they form. Soda has in general a weaker attraction to the acids than potash has, and the salts which they form with the same bases are very different in their properties.

From experiments similar to those from which the composition of potash is inferred, it is supposed that soda is a compound of magnesia and hydrogen, or, according to others, of magnesia and azot. It is not certain whether the soda is formed during the burning of those sea plants from which it is obtained, or whether it pre-exists in them in the state of muriat of soda, or of some other combination.

Both

Both soda and potash exist as constituent principles of several mineral substances.

Sect. II. — COMBINATIONS OF OXYGEN IN GENERAL.

THE attractive power of oxygen towards other bodies is more extensive than that of any other chemical agent, and the history of its combinations forms the most important part of chemical science. * These combinations are very generally attended with the emission of light and caloric,---in other words, with the phenomena of combustion : it is therefore necessary to take a general view of this important process, before proceeding to the consideration of its particular products.

The phenomena of combustion, and the distinction of bodies into combustible or inflammable, and incombustible or unflammable, are sufficiently familiar. The latter, when exposed to heat, have their temperature raised, and that in proportion to the degree of heat applied to them ; but whenever this communication of caloric, from an external source, is stopt, their temperature falls, and they return to their former state. Combustible
bodies,

bodies, on the contrary, when heated to a certain extent, begin to suffer a very evident change,—they become much hotter than the surrounding bodies, emit light more or less copiously, and appear to be consumed, or rather are converted into substances altogether new, and which frequently are not apparent to the senses. It is this rapid emission of light and caloric, and this change of properties, and apparent loss of substances, which constitute the process of combustion.

Beccher advanced the first rational chemical hypothesis to account for these phenomena; he ascribed them to the motion of a peculiar principle, the inflammable earth, which he supposed all inflammable bodies to contain. Stahl, refusing on this system, admitted with Beccher the existence of a common principle in inflammable bodies, to which he ascribed their inflammability: but this principle, which he termed Phlogiston, he supposed not to be an earth, but fire, or the matter of heat and light. In combustion he supposed it to be disengaged, and hence explained the phenomena attending that process, and the change of properties in the bodies subjected to it. This hypothesis appearing to afford a satisfactory explanation of a number of chemical phenomena, was universally

universally adopted, nor for a considerable period was any doubt entertained of its truth.

In framing this hypothesis, Stahl paid no attention to the influence of the air in combustion, which before his time had been demonstrated, and the nature of it in some degree ascertained, by the experiments of Mayow and Boyle. So far, therefore, it was defective, as it gave no explanation of the necessity of the presence of the air for the support of that process. It had further been ascertained, that some bodies, instead of losing, gain weight by combustion — a fact inexplicable on the Stahlian doctrine, since it supposed that in that process a principle was merely disengaged from the combustible body.

Various attempts were made to solve these difficulties, but with little success; and the discoveries which were soon after made of the nature and agency of the gases, pointed out still more clearly the deficiency of the original doctrine. It was observed, that combustion was more vivid in oxygen gas; and it was shewn by different chemists, that when it is carried on in atmospheric air, the weight and volume of the air are diminished to a certain extent, and it is no longer capable of supporting

that process, changes which were likewise proved to be owing to the consumption of oxygen. These facts led to a new system. While the greater number of chemists laboured to reconcile them with the hypothetical ideas of Stahl, and for that purpose proposed many modifications of his doctrine, Lavoisier at once rejected it, denied the existence of Phlogiston, and ascribed the phenomena of combustion to the combination of oxygen with the inflammable body. By this combination, the changes it suffers in properties and in weight, as well as the corresponding changes in the air, were accounted for: and as the doctrine of latent heat had been previously established, the evolution of caloric was thus also explained.

According to this doctrine, then, inflammables are merely substances, having an attraction to oxygen, and which, at a certain temperature, are disposed to combine with it: Combustion is this combination; the product of that process is the compound which results from it; and the evolution of caloric which accompanies it, is not from the inflammable body, but from the oxygen gas.

The first principle of this theory, that combustion is the combination of oxygen with the combustible

combustible body, is proved by the following general facts: 1st, Combustion cannot go on without the presence of oxygen; and is more rapid in proportion to the quantity of oxygen in contact with the inflammable body. 2dly, In every case of combustion, the oxygen present is consumed; 3dly, The increase of weight which every combustible body gains in burning, corresponds exactly to the weight of the quantity of oxygen gas which disappears; and, 4thly, The quantity of oxygen absorbed by the combustible body, may always be recovered from the compound that has been formed, and its weight is equal to the weight of the quantity which had disappeared during the combustion. These facts have been established by the most accurate experiments; they are true without limitation or exception, and their force in establishing the conclusion that combustion is the combination of oxygen with combustible bodies, cannot be eluded but by the most extravagant and unfounded suppositions.

From this principle, respecting the nature of the process termed Combustion, it remains to explain the phenomena which attend it, the principal of which is the evolution of light and caloric.

By

By the older chemists it was universally supposed, that the caloric proceeded from the inflammable body; and this is indeed an opinion which must appear unquestionable, while the nature of combustion is not perfectly understood. The burning body appears luminous and feels intensely hot; and as no other agent appears to be concerned, the conclusion seems unavoidable, that it is from it that the light and heat are evolved. But when the nature of the influence of the air in combustion is understood, when it is proved that in that process oxygen combines with the combustible body, it is obvious that this conclusion no longer necessarily follows, since where two substances combine, if light and caloric are evolved, it is *a priori* equally probable that they may proceed from the one or from the other. Whether they proceed from the oxygen gas or the combustible body, they must be separated at the part where the combination takes place, that is, upon the surface of the burning matter itself; and consequently it will appear luminous and heated, while the gas being invisible escapes observation. When it is further ascertained, that bodies in the aeriform state contain in equal weights, and at the same temperature, quantities of caloric much greater than solids or fluids do, the conclusion becomes

comes

comes probable, that the caloric evolved in combustion proceeds rather from the oxygen gas than from the combustible matter, since the former contains a much larger quantity of this power than the latter. This is accordingly the explanation that was first given in the modern system, of the origin of the caloric evolved in combustion. The greater number of combustible bodies exist in the solid or fluid state, and the compound formed by the combustion likewise generally exists in one of these forms; the caloric extricated was therefore supposed to be derived from the *condensation* of the oxygen gas in the new combination into which it enters.

Though approaching to the truth, this explanation is not strictly true. It is not merely from the oxygen gas being *condensed* that the caloric is evolved, because in many cases of combustion the product still exists in the gaseous form, and because the quantity of caloric evolved in different cases, bears no proportion to the degree of condensation. Dr. Crawford, considering this subject under a more extensive point of view, determined by numerous experiments, that the evolution of caloric which attends combustion, is owing to change of capacity. He found that the capacity

capacity of oxygen gas is much greater than the capacities of combustible bodies; he likewise ascertained that the capacity of the compound resulting from the combustion, is always much less than that of the oxygen gas, while it is almost invariably greater than the capacity of the combustible body, though still inferior to the mean of the capacities of the two; it is therefore evident, that caloric *must* be rendered sensible during combustion, and that it is from the oxygen gas that it must be evolved. In different bodies the difference in the proportion of the capacities before and after combustion is by no means uniform; and hence the difference in the quantities of caloric extricated in various cases of combination, a difference augmented by the variations in the degree of rapidity with which oxygen and the different combustible bodies combine,

Some chemists have given a different representation of this subject. They suppose that oxygen gas is a chemical compound of oxygen and caloric; that in combustion the oxygen is attracted by the inflammable body, and that by this superior affinity, the caloric is disengaged. "At a certain degree of temperature," says Lavoisier, "oxygen possesses a stronger elective attraction
" or

“ or affinity for phosphorus, than for caloric ;
“ and in consequence of this, phosphorus attracts
“ the base of oxygen gas from the caloric, which,
“ being set free, spreads itself over the surround-
“ ing bodies.” He gives a similar explanation
of every other case of combustion.

It is not difficult to determine which of these explanations, or rather which of these modes of expressing the same explanation, is preferable. Unless the experiments of Crawford, proving that a diminution of capacity takes place, when oxygen combines with inflammable bodies, are invalidated ; or unless it is shewn, that the difference in the quantities of caloric contained in different bodies, which is expressed by saying, that they have different capacities, is owing to that part of the caloric contained in each above that contained in the others, being chemically combined with it, it must be evident, that the language which supposes such a combination involves an hypothesis, and is consequently unphilosophical, while the other is strictly inferred from the phenomena, and, as Dr. Crawford remarks, it is equally adapted to explain them, whatever opinion may be held respecting the nature of caloric, or its mode of existence.

It

It remains to explain the origin of the light emitted during combustion. While it was believed that light and caloric were essentially the same, the same origin was necessarily assigned to both : in the ancient system, they were supposed to proceed from the inflammable body ; in the more modern theories they have been derived from the oxygen gas. But as this opinion, with regard to the identity of these two agents, is unfounded, it is still necessary to enquire whence the light is derived ; for it is evident, that from the fact that the caloric is disengaged from the oxygen gas, we cannot infer, that the light must have the same origin.

Lavoisier, though he inclined to the opinion that light is a component part of oxygen gas, and that it is from the decomposition of this gas that it appears during combustion, did not consider it as fully established. Fourcroy supposes it to be demonstrated by the following facts, which other chemists have likewise urged in support of the same opinion. “ Combustible bodies afford much
“ more flame when they burn in oxygen gas alone,
“ than in atmospheric air : there are combustible
“ bodies which do not burn with flame, except in
“ oxygen gas : to disengage the oxygen from bodies

" dies which contain it, and convert it into oxygen gas, it is not sufficient to dissolve it in a greater or less quantity of caloric, but it is necessary at the same time to add light : and lastly, there are burnt bodies which lose their oxygen on the contact of light alone."*

These facts prove nothing, and it is singular that they should have been considered as of any weight. With respect to the two first, it is obvious, as combustion is more rapid in oxygen gas than in atmospheric air, that, from whatever source the light may be derived, a greater quantity must be evolved in a given time. And with respect to the two last, it is equally evident that they are explained, as well by the supposition that light has an attraction to the base of the inflammable body, as to the base of the oxygen gas ; nor are the facts themselves more in favour of the one supposition than of the other.

Although there is no decisive proof that light is a constituent principle of inflammable substances, there are various considerations which render

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* Philosophy of Chemistry.

it probable. It is frequently evolved in combinations of oxygen, where the oxygen is merely transferred from one inflammable substance to another : but in such cases it is highly probable that it must proceed from the inflammable body ; since, even supposing it to be a component principle of oxygen gas, it must have been evolved in the combination of the oxygen with the body from which, in these cases, that principle is transferred. The oxydation of certain metals, by heating them with other oxyds, as with oxyd of mercury, and the deflagrations excited by the action of sulphuric, nitric, and oxygenated muriatic acids, upon inflammable bodies, afford examples of this kind. Other experiments have been made, apparently still more decisive, in which light was evolved, when the filings of different metals were heated with sulphur *in vacuo*, or under mercury, when of course no oxygen was present to afford it. These indeed have been objected to, on the supposition that water was present in the materials, from which oxygen might be derived. But, granting this supposition, which seems, however, not to be established, it does not invalidate the argument, that the light must have proceeded from the inflammable body ; since, supposing light to exist in oxygen gas, still it must have been evolved in the combustion

combustion of hydrogen, by which water is formed ; and of course could not exist in that water, or in either of its principles.

It seems probable, therefore, that the light extricated in combustion, is derived from the inflammable substance ; the oxygen combining with the bases of these substances, and disengaging the light by a superior affinity. It is possible that part of it may also be derived from the oxygen gas ; but it is evidently unnecessary to *suppose* so, where the supposition is supported by no fact.

It may be concluded, then, that inflammable bodies are compounds, consisting of light united with unknown bases ; but as we are unable to separate the light, so as to obtain these bodies pure, it is unnecessary to arrange these substances as compounds. This opinion was first maintained by Macquer, and has been revived by Gren. Some have affected to consider it as a modification of the doctrine of Stahl, light being substituted for phlogiston. But this is a mere verbal conceit, which could have originated only from prejudice in favour of that hypothesis.

Besides

Besides the simple case of the combination of oxygen with other bodies, which constitutes combustion, there are some others more complicated, in which, after being combined with one body, it is transferred to another.

Deflagration is a case of this kind. When a quantity of nitre, or nitrat of potash, is mixed with an inflammable body, and exposed to a red heat, a vivid combustion is immediately excited. This is termed Deflagration. The general explanation of it is sufficiently evident. Nitre consists of potash and nitric acid, the latter being a compound of oxygen and azot. The nitre, therefore, contains a large quantity of oxygen, which exists in it in a state of combination so weak, that it is separated by exposure to heat; it is therefore easily transferred to the inflammable body, and hence the vivid combustion that is excited. Any other salt, containing the nitric or oxygenated muriatic acid, produces the same effect.

There is a difficulty in explaining the origin of the quantity of caloric rendered sensible during deflagration. The oxygen exists in the salts concerned in that process in a concrete state, and it can scarcely be supposed to contain, in such a state,

state, that large quantity of caloric which it contains in the gaseous form. Whence then is the caloric which is extricated derived?

It must first be remarked, that the quantity of caloric rendered sensible during deflagration is proved, by the experiments of Lavoisier with the calorimeter, to be considerably less than that evolved from the consumption of the same quantity of oxygen by combustion. Still a large quantity is evolved. It has been ascertained, however, that when nitric acid is formed by the combination of oxygen and azot, each previously existing in the state of gas, much less caloric is disengaged than in other combinations of oxygen: it is also known, that when this acid is combined with potash to form nitre, a very inconsiderable quantity of caloric is discharged. It is evident, therefore, that a very large quantity of the caloric contained originally in the oxygen gas remains in the nitre; and this will account for the quantity rendered sensible in deflagration.

It has been affirmed, that the capacity of nitre for caloric is not great, and that the united capacities of nitre and charcoal, are inferior to the united capacities of the products of the deflagration

tion of these substances. Were this accurately determined, it would not invalidate the above facts, though it would furnish a strong argument in favour of the doctrine, that caloric exists in a state of chemical combination---a doctrine which indeed completely solves the present difficulty. But the fact itself has not perhaps been determined with sufficient accuracy ; and in the reasoning founded upon it, the quantities of the substances acted on in deflagration seem to have been neglected, a very large quantity of nitre being necessary for the complete deflagration of a quantity of charcoal.

The origin of the light extricated in deflagration must be explained in the same manner as its appearance in combustion.

From the quantity of azotic gas disengaged in those cases of deflagration in which nitrous salts are used, if the materials be inclosed in a metallic tube, previous to its being kindled, a strong expansive force is exerted, and an explosion takes place, which is still greater where the substance deflagrated is one which, when combined with oxygen, produces a compound existing in the gaseous form. This is termed *Detonation*. There
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are some cases of it, in which such a quantity of heated gas is suddenly extricated, that the resistance even of the surrounding atmosphere is sufficient to occasion the same phenomenon.

The last case of the combinations of oxygen is that where it is transferred from one body to another, without being accompanied by the phenomena of combustion. Thus all the acids contain oxygen: it frequently happens, when an acid is poured upon an inflammable body, that its oxygen is attracted by the latter, and the other component principle of the acid is disengaged. Water, which is a compound of oxygen and hydrogen, is often decomposed in a similar manner.

In such cases, the extrication of caloric which takes place is much less considerable than in combustion, partly from the oxygen as it exists in the acid having been deprived of a large portion of its caloric, and partly from the absorption of caloric by the products of the decomposition. Neither does any disengagement of light attend this process; probably because it passes from the inflammable body, to the base with which the oxygen was united in the body decomposed.

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The combination of oxygen with any body is termed in general its *Oxydation*, or *Oxygenation*. When the compound which results has a sour taste, is capable of reddening the vegetable colours, and of combining with the alkalis and earths, it is termed an *Acid*; when it possesses none of these properties, it has the name of *Oxyd*. Oxyds and acids, therefore, are two orders of compounds resulting from the combinations of oxygen. In general, the oxyd is the product of the first degree of oxygenation, or of that combination in which the body is united with a small proportion of oxygen; while a compound of an acid nature is produced by a higher degree of oxygenation. To this, however, there are many exceptions. There are substances which are incapable of being acidified; they are either only capable of uniting with oxygen in one proportion, and produce an oxyd, or, if they unite with it in different proportions, the products are always oxyds distinguished by different properties. There are other substances, again, which form acids, even in the first degree of oxygenation; at least, their existence in the state of oxyd has not been unequivocally proved. But in all those substances which, by combining with oxygen in different proportions, produce both oxyds and acids, the
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oxyd is invariably the product of the first degree of oxygenation, and the acid results from the addition of a larger proportion of oxygen.

The order of oxyds is distinguished by no common properties, except, perhaps, the general one, of combining with greater facility with a larger proportion of oxygen. The term was introduced merely as a convenient one to denote those compounds, the products of oxygenation, which have no acid properties.

Acids, on the contrary, have certain common properties by which they are distinguished. They are sour to the taste, act as caustics on animal matter, have a strong attraction to water, change the vegetable colours to a red, oxydate inflammable and metallic substances, and combine with the alkalis, the earths, and metallic oxyds, forming compounds in which the properties of the acid, or of the substance with which it is united, no longer exist.

The same substance is in several instances capable of uniting with two proportions of oxygen, so as to form two *acid* compounds, different in their properties from each other. Thus sulphur,

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with a certain proportion of oxygen, forms an acid, which exists in the state of gas; and with a larger proportion, another acid, which requires a strong heat to volatilise it: and in like manner phosphorus and azot, by different degrees of oxygenation, form different acids. In the new nomenclature, the names of these compounds are expressed with much perspicuity. The name of the acid is always derived from the particular substance from which, by combination with oxygen, it is formed; and the difference in the state of the acid, from the different degree of oxygenation, is expressed by a variation in the termination. Thus the acid formed from sulphur with the less proportion of oxygen, is termed the Sulphureous acid; that with the greater proportion, the Sulphuric; and in like manner we have the Phosphorous and Phosphoric, the Nitrous and Nitric, denoting the different acids from the same base. One or two acids are capable of combining with a still larger proportion of oxygen, which rather impairs than increases their acid properties. To denote these acids in this state, the term Oxygenated is prefixed to their usual names.

The compounds which the acids form with the alkalis, earths, and metallic oxyds, are termed
Neutral

Neutral Salts. They are in general soluble in water, are capable of crystallization, and have much less activity as chemical agents than the acids or the base from which they are produced. The nomenclature of these salts is precise and systematic. All the salts, containing the same acid, are considered as forming one genus, to which as many species belong as there are salts formed by the union of that acid with alkalis, earths, or metallic oxyds. The generic name is derived from the name of the acid, the specific name from that of the base with which it is united. Thus all the salts formed by the sulphuric acid are termed Sulphats; as the Sulphat of Potash, of Soda, of Lime, &c.; and the same nomenclature is extended to the others. The names of the salts formed by the acids with a less quantity of oxygen, are expressed by a variation of termination; those containing the sulphureous acid are termed Sulphites; and in like manner we have Nitrats and Nitrites, Phosphats and Phosphites, &c.

Seçt. III. — — OXYGEN WITH HYDROGEN

WATER.

OXYGEN, when combined with any simple inflammable body, not metallic, to the point of saturation, forms an acid. The present case is the only exception: oxygen and hydrogen can be combined in only one proportion, and water is invariably the result of this combination.

The idea of the composition of water seems to have occurred about the same time to Mr Watt and Mr Cavendish; the former inferring it from some experiments in which it was decomposed; the latter, from finding that when oxygen and hydrogen gases are fired together, water is the only sensible product. The latter experiment was soon after performed on a large scale, with the greatest accuracy by Lavoisier and the French chemists, with the same result. The discovery, besides its intrinsic importance, derived an adventitious consequence at that time, from its intimate connection with the explanations of
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the antiphlogistic system, which were then warmly contested : it was therefore reluctantly admitted ; and there were certain ambiguous circumstances in the experiments by which it was established, that afforded, in some degree, reasons for doubt. It was observed in particular, that the water produced was frequently acid ; hence it was concluded, that this acid was the real product of the combination, and that the water deposited was only the quantity held in solution by the gases. The origin of this acid, however, was satisfactorily explained. It was found to be either carbonic or nitric acid : ---the former is derived from a small quantity of carbon, which the hydrogen, when prepared from certain materials, often contains ; the latter from a portion of azot, of which it is extremely difficult to obtain oxygen entirely free. It was also at one time affirmed, that the quantity of water produced is not equal to the quantities of oxygen and hydrogen consumed ; but the contrary has been established by the most accurate experiments on a large scale ; experiments which obviate every objection, and leave scarcely any doubt as to the composition of water. The proportions of its principles have been stated at 85 parts by weight of oxygen, and 15 of hydrogen, or rather 85,662 to 14,338.

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The composition of water has likewise been established by its analysis. When passed over iron, zinc, or charcoal heated to ignition, its oxygen is attracted by any of these substances, and its hydrogen is disengaged. Even at a low temperature, iron or zinc can decompose water with rapidity, when its attraction to oxygen is promoted by the *disposing affinity* of an acid.

Water has also been decomposed by the agency of electricity. If an interrupted electrical discharge be made to pass through a quantity of the fluid, it is resolved into oxygen and hydrogen gases, and the mixture of these may be inflamed by the electric spark so as to form water. Still more lately a decomposition of it has been found to be effected by the galvanic influence, discharged by the pile of Volta, so singular as to have given rise to doubts respecting its composition. If, as has been formerly remarked, a wire from the top, and another from the bottom of the pile, be inserted in a tube of water, so as that their extremities shall be distant one or two inches, a stream of hydrogen is emitted from the one wire, and of oxygen from the other. If the water is decomposed at these points, what becomes of the oxygen at the one point, and of the hydrogen at the other?

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This is a question not easily answered. It has even been affirmed, that a given quantity of water may be converted entirely into oxygen, or hydrogen, according as it is connected with the top or bottom of the pile; and it has been concluded, that the established opinion respecting the composition of water is false. Such a conclusion, however, is too hasty, while we remain so little informed as to the nature of the agency of this power, and are unable to give any satisfactory explanation whatever of its effects.

The general properties of water are well known. When pure, it is tasteless, inodorous, colourless, and transparent. Like other bodies, it owes its fluidity to the operation of caloric, ice being its more natural state; by the farther action of that power, it is also converted into vapour.

As a chemical agent, water is of the first importance. It is capable of combining with a very great number of bodies; few indeed are altogether exempt from its action. It absorbs small quantities of the simple gases, and is also dissolved by them, and retained by a force of attraction so great, that it is not certain if they can be entirely freed from it. Of these gases it seems to have the
strongest

strongest attraction to oxygen ; a circumstance which explains several chemical and natural phenomena. It also absorbs a quantity of atmospheric air, which renders it sparkling, and causes it to sit lighter on the stomach. Water is the solvent of all saline bodies, and it is to its presence that they owe their crystalline form. It is likewise capable of dissolving earths and stones in greater or less quantity, and still more of reducing them by attrition to a state of extreme mechanical division. It exerts a considerable action on the metals, affording them oxygen slowly, even at a natural temperature. Lastly, it is the solvent of the greater number of the animal and vegetable products, and by communicating fluidity to them, facilitates their spontaneous decomposition. Water, therefore, from its extensive agency, is of the first importance in the economy of nature, and is the immediate instrument by which many important operations are performed.

From the great solvent power of water, it can never be obtained perfectly pure, but by art. Spring water, river water, &c. are all impregnated with saline, earthy, and even metallic bodies, in quantities more or less considerable, according to the strata over which the water has run. Rain
water

water is free from these impregnations, but it is always found to have imbibed a quantity of atmospheric air, or of carbonic acid; and in the neighbourhood of cities, it is rendered still more impure. Water is rendered perfectly pure by distillation; and for any chemical process, in which much accuracy is requisite, distilled water must always be employed.

Seét. IV. — — OXYGEN WITH AZOT.

OXYGEN and Azot *mixed* together, form atmospheric air; when *combined* in various proportions, they form not less than four compounds :---Nitric Acid, consisting of about four parts of oxygen to one of azot; Nitrous Acid of 3 to 1; Nitrous Gas of 2 to 1; and Nitrous Oxyd of rather less than an equal part of oxygen.

NITRIC ACID:

THE acids which result from the combination of oxygen with azot, had been long known to chemists, but their chemical composition was unknown till discovered by Mr. Cavendish. On taking the electric spark for some time in atmospheric air, he found that its volume was diminished, and that if the experiment was performed over water, it became sensibly acid. On examining this acid, he found it to be the nitric; and therefore concluded, that it is a compound of oxygen and azot. The proportions he states at 72.2 of oxygen, to 27.8 of azot. Lavoisier supposes them to be rather 79 to 20; while Mr. Davy has lately reduced the proportion of oxygen so low as 70.5 of oxygen, to 29.5 of azot. The acid, however, produced in Cavendish's, and perhaps in Davy's experiments, is not the pure nitric, but the nitrous, which contains a less proportion of oxygen than the other. The combination of these gases with each other is singular, in not being accompanied with the emission of light, and with the extrication of a very inconsiderable quantity of caloric.

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The composition of nitric acid is confirmed by its analysis. If passed through an ignited glass or earthen tube, it is converted into oxygen and azotic gases: or if acted on by an inflammable substance, which can attract its oxygen, it is converted into nitrous gas; and this, by a further abstraction of oxygen, is converted into azot.

Nitric acid cannot be produced in any considerable quantity by the direct combination of its principles; chemists, therefore, prepare it by decomposing the compound of it with potash, the nitrat of potash, or nitre of commerce, a salt which is produced in great abundance in warm climates, either spontaneously, or by the aid of artificial arrangements. Two parts of this salt in coarse powder are put into a glass retort, and rather more than one part of a peculiar acid, the sulphuric, is poured upon it, and heat applied. This acid exerts a strong attraction to potash, and combines with it, and the nitric acid is disengaged. From the degree of heat which is necessary to distil it over, and from the influence of the disposing affinity of the acid itself to nitrous gas, it suffers a partial decomposition, part of its oxygen is separated, and the product of the process is not *nitric*, but *nitrous* acid. But *this* is easily converted

converted into nitric, by exposing it to a moderate heat in a water bath, by which the nitrous gas which it contains, and which renders it red and fuming, is expelled.

Nitric acid thus obtained is a colourless transparent fluid, possessing in a very eminent degree all the general properties of acids. Its specific gravity, when concentrated, is 1.554; but in this state it still contains a quantity of water, from which it cannot be entirely freed, even by freezing. Exposed to the air, it emits white coloured fumes, and imbibes moisture. In combining with water it produces heat; poured on snow or ice, it melts it, and produces intense cold. It is partially decomposed by a temperature very moderately increased; and by the temperature of ignition, is converted entirely into oxygen and azotic gases. Light likewise decomposes it partially, expels part of its oxygen, and renders it coloured and fuming. It is not sensibly affected by any of the simple gases.

This acid unites rapidly with the alkalis, and exerts to them a strong attraction. Its attraction is strongest to potash, and weakest to ammonia. These combinations form an order of neutral salts, termed

termed *Nitrats*, the general properties of which are their cool penetrating taste, their affording oxygen gas by exposure to heat, emitting red fumes when heated with sulphuric acid, and deflagrating with inflammable bodies.

1st. NITRAT of POTASH. This salt, the Nitre or Saltpetre of commerce, is produced by nature in abundance in warm climates. It is found mixed with the soil at the surface of the earth, and is separated from its impurities by solution in water and crystallization. In colder climates the formation of it is assisted by art. Animal and vegetable matters in a state of putrefaction are mixed with old mortar, or carbonat of lime, and formed into heaps, which are covered with sheds to protect them from the rain, but which give access to the air; after some months, these materials are washed with water, when they afford the compound salts, which consist of nitric acid with potash, and with lime. To the solution a quantity of potash is added, by which the nitrat of lime is decomposed, and the nitrat of potash is obtained pure by successive solutions and crystallizations.

The circumstances indispensable for this formation of nitre, are the presence of animal and vegetable

getable matter mixed with lime, a certain degree of moisture, and the access of atmospheric air. During the process, the nitric acid is formed. By the slow decomposition which the animal matter undergoes, azotic gas is disengaged, and is presented in a nascent state to the oxygen of the atmosphere, whence the formation of the acid : the presence of the vegetable matter seems useful by moderating the putrefaction, and perhaps also by furnishing a quantity of oxygen with which the azot combines ; the lime acts probably by a disposing affinity, promoting the combination of the oxygen and azot, and afterwards attracting the acid that is formed ; and the superiority of carbonate of lime to the earth in its pure state, or to the alkalis, a fact which has been ascertained by experiment, is probably owing to these latter substances, acting too rapidly on the animal matter, combining with part of it, and resolving the other part into ammonia : lastly, the utility of moisture may be explained, from its absorbing and retaining in some measure the disengaged gases, and diffusing thro' the materials the nitrous salts when they are formed. Experiments render it probable, that in this process a quantity of potash is also produced.

Nitrat

Nitrat of potash, according to Kirwan, is composed of 44 of nitric acid, 51.8 of potash, and 4.2 water of composition. It crystallizes in octohædral prismatic crystals, its taste is cool and penetrating, it is soluble in 7 parts of water at 60°, and in an equal weight of boiling water, melts on the application of a moderate heat, and by a stronger heat is decomposed, its acid being resolved into oxygen and azotic gases.

Heated with inflammable substances, nitrat of potash excites a vivid combustion or deflagration, by yielding its oxygen. From this property it is applied to an important purpose in the composition of gunpowder, which is a mixture of it with charcoal and sulphur. When an ignited particle is introduced into this mixture, it excites a vivid combustion, which is rapidly propagated through the whole mass; and large quantities of azotic, carbonic acid, and sulphureous acid gases with aqueous vapour being extricated, the elasticity of which is much increased by their high temperature, a powerful expansive force is produced. A similar composition still more powerful, is the *pulvis fulminans*, composed of nitrat of potash, carbonat of potash, and sulphur. This, when merely heated without being confined, detonates with violence, probably

probably from the rapid production of sulphurated hydrogen, which, combining with the oxygen of the nitre, instantly forms sulphureous acid gas and aqueous vapour, the elasticity of which is at the same time much increased by the quantity of caloric suddenly extricated.

2. NITRAT of SODA. This salt, not being found in nature, is formed artificially by the combination of its principles. Its taste is cool and penetrating; it is soluble in 3 parts of water at 60° , and in an equal weight of boiling water: it crystallizes from the latter solution, its crystals being of a rhomboidal figure. It is fused and decomposed by heat, like nitrat of potash; and, like it, it deflagrates with inflammable substances. It consists, according to Kirwan, of 53.21 of acid, 40.58 of soda, and 6.21 water of composition.

3. NITRAT of AMMONIA. This salt is likewise prepared by art. It has a cool bitter taste, is soluble in 2 parts of water at 60° , and in half its weight of boiling water, the latter solution affording, by cooling, prismatic crystals. These consist of 57 parts of acid, 23 of ammonia, and 20 of water. They are slightly deliquescent. Exposed to heat, they undergo the watery fusion. When the

the temperature is above 300 , the salt is decomposed, the hydrogen of the ammonia attracts part of the oxygen of the acid, and forms water, and the remaining oxygen combines with the azot of the acid and the azot of the alkali, and forms a peculiar compound, termed Nitrous Oxyd, or Gaseous Oxyd of Azot. When the temperature is raised above 600°, the decomposition is more rapid, accompanied with detonation, from the sudden production of aqueous vapour and azotic gas.

Nitric acid acts with violence on inflammable substances, and is decomposed more or less completely, by the greater or less abstraction of its oxygen by the inflammable body. It likewise oxydates and dissolves the greater number of the metals.

NITROUS ACID.

NITRIC is converted into Nitrous Acid by whatever abstracts a portion of its oxygen. The common mode of obtaining this latter acid, however, is merely to decompose the nitrat of potash by sulphuric acid, with the assistance of

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heat.

heat. The nitric acid, as has been observed, suffers a partial decomposition during the process, and hence it is the nitrous which is obtained by distillation. It differs from the nitric in being of a yellow or orange colour, and in emitting copious red fumes. It is highly corrosive, and possesses all the acid properties in an eminent degree. It exists in the state of gas; but in that state it cannot be properly examined, as no substance can be used to confine it. In its liquid state, in which it is combined with a quantity of water, its specific gravity, when concentrated, is 1580. It has a strong attraction to water, and their combination is attended with an increase of temperature. As a disengagement of nitrous gas attends this combination, it seems to be the nitric, not the nitrous acid, that unites with the water.

The composition of nitrous acid has been variously stated. Cavendish concluded, that it consists of more than 2 parts of oxygen to 1 of azot. Lavoisier states the proportions at 3 to 1; and more lately, Mr. Davy makes the proportions in the pale yellow acid to be 70.1 to 29.9, and in the deeper orange coloured, 69.6 to 30.3. There seems, indeed, to be no acid, a compound of oxygen and azot, in one uniform determinate proportion,

proportion, different from the nitric; the nitrous being nothing but the nitric, holding in solution a greater or less quantity of nitrous gas, and being more or less coloured, according to the quantity it contains.

Nitrous acid acts upon inflammable substances and metals, in the same manner as nitric, oxydating them, and frequently combining with the product of this oxydation. It combines with the alkalis, forming salts, which, according to the principles of the new nomenclature, are termed Nitrites. These cannot be formed by adding the acid to the alkali, the nitric acid only entering into combination, and the nitrous gas being disengaged. They can be obtained by decomposing partially the nitrats by a moderate heat, a small quantity of oxygen being expelled, and the nitrous acid remaining combined with the base. These salts, however, are rather to be considered as compounds of nitric acid and the substances with which it is united, to which a portion of nitrous gas adheres; and this gas can be expelled by the addition of any weak acid. In their properties they are very similar to the nitrats.

NITROUS GAS.

THIS compound of oxygen and azot has a less proportion of oxygen in its composition than the former, and differs from them in having no acid properties. It exists in the state of permanent gas. The easiest mode of obtaining it is, to decompose the acid by means of a metal. Upon one part of copper wire, one part of nitric acid, diluted with three parts of water, is poured, and a very gentle heat is applied; the metal attracts part of the oxygen of the nitric acid, and the product is nitrous gas, which is discharged with effervescence, and may be collected in jars placed over water. It is permanently elastic and colourless; it is absorbed by water in very inconsiderable quantity; it does not redden any of the vegetable colours, or shew any acid properties; its specific gravity is to that of atmospheric air as 119 to 100. It is fatal to animal life, and proves nearly as noxious to vegetables. It is likewise incapable of supporting combustion in general, though there are some substances which burn in it with splendour. It is not inflammable.

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The most striking and important property of this gas, is the facility with which it combines with oxygen gas. If atmospheric air be admitted, red fumes immediately appear from the formation of nitrous acid, and the volume of the air diminishes, from the combination of its oxygen with the nitrous gas; when oxygen gas is admitted, the diminution of volume is more rapid, and, if the two gases are pure, there is no residuum. About one part of oxygen is necessary to saturate $2\frac{1}{2}$ parts of nitrous gas. During this combination, no light is extricated, and very little caloric.

This property of nitrous gas of combining with oxygen gas, at natural temperatures, and of forming a compound easily absorbed by water, has been applied to the purpose of eudiometry. A given quantity of the gas is added to the air, containing oxygen;--- the diminution of volume produced, is measured by a graduated tube, and the quantity of oxygen present estimated from the quantity of nitrous gas necessary to be added to produce the full diminution. This method, however, though simple in the management, is of all others the most inaccurate, the results being influenced by various minute circumstances; as, the

the size of the vessels, the degree of agitation employed, and the time during which they are allowed to stand, and the nitrous gas itself being always mixed with a greater or less proportion of azot.

Nitrous gas scarcely combines with either of the other simple gases; mixed with hydrogen, it causes it to burn with a green flame. Neither does it combine with ammonia, or with the fixed alkalis. It is decomposed by a number of inflammable substances which abstract its oxygen partially or completely, and convert it into nitrous oxyd or azot. By the agency of the electric spark, it is changed into azot, and nitrous acid.

The proportions of nitrous gas are stated by Lavoisier at 32 of azot and 68 of oxygen; by Davy, at 44 and 56.

NITROUS OXYD, — GASEOUS OXYD OF AZOT.

THE compound to which these names are applied, is that in which oxygen is combined with azot in the least proportion. It is obtained by various processes in which nitrous gas or nitric acid is

is decomposed, by substances capable of attracting the greater part of their oxygen. It is thus produced by exposing nitrous gas to the alkaline sulphites or sulphurets, to muriat of tin, fulphurated hydrogen, or hydrogen in its nascent state; and it is extricated, mixed with azot, and with nitrous gas, during the solutions of zinc, iron, and other metals, in nitric acid. The most convenient mode of obtaining it is by the decomposition of nitrat of ammonia by heat. At a temperature between 340° , and 480° , both its constituent principles are decomposed; the azot of each combines with a portion of the oxygen of the acid, and forms the nitrous oxyd; the hydrogen of the ammonia combining with the remaining oxygen of the acid, and forming water. Mr. Davy has shewn, that this is the only process by which it is obtained pure; and that former chemists, having obtained it by other processes, had always examined it in an impure state.

Nitrous oxyd exists in the form of permanent gas; it produces no change in the vegetable colours, and suffers no diminution of volume when mixed with oxygen or nitrous gases. It is absorbed by water, the water, at a mean temperature, taking up about half its bulk.

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This compound does not directly combine with the alkalis, or their solutions; but when it is presented to them in their nascent state, the combination is effected. These compounds deflagrate when heated with charcoal, and are decomposed by the acids, the nitrous oxyd being disengaged.

One of its most distinguishing properties is its capability of supporting combustion. Phosphorus burns in it with splendour, and sulphur with a vivid rose-coloured flame. That bodies may burn in it, it is necessary that their temperature should be raised considerably higher than that at which their combustion takes place in oxygen gas or atmospheric air.

The effects produced on the animal system by the respiration of this gas, are of the most singular kind, and eminently distinguish it from every other chemical agent. It had always been supposed to be, equally with the other compound gases, noxious to life; but the experiments which appeared to support this opinion were made with this gas in an impure state. Mr. Davy, by obtaining it pure, ascertained that it could be breathed with safety; and discovered the singular effects it produces. It acts as the most powerful stimulant,

lant; excites every fibre to action; produces a sense of thrilling over the whole body, frequently accompanied with sensations of the highest pleasure; and rouses the faculties of the mind, inducing a state of high exhilaration, which, in general, is not followed by languor or debility, but rather by vigour and a disposition to exertion, continuing for some time, and gradually subsiding. These effects are produced, either when it is inspired pure, or mixed with atmospheric air; in its undiluted state, the inspiration of it cannot be continued above four or five minutes, as insensibility is induced: an animal confined in it dies even sooner than in oxygen gas or atmospheric air, apparently from the high excitement it occasions. From its highly stimulant powers, it has been applied with advantage to the treatment of several diseases of debility.

The analysis of nitrous oxyd is performed by the electric spark, or by passing it through an ignited earthen tube. It is thus converted into nitric acid, and a gas analogous to atmospheric air. From analytic experiments of this kind, Mr. Davy concludes, that it is composed of 37 parts of oxygen with 63 of azot.

CHAP. III.

SIMPLE INFLAMMABLES, AND THEIR BINARY COMBINATIONS.

UNDER the title of Simple Inflammables, may be arranged three substances, Carbon, Sulphur, and Phosphorus. Their general characters are, that they exist in the solid form, but are totally destitute of the metallic splendour, opacity, and gravity; they are highly inflammable, and form acids by combination with oxygen.

CARBON.

CARBON.—DIAMOND.

WHEN vegetable matter, especially the wood of plants, is exposed to heat in close vessels, the more volatile parts are expelled or decomposed, and there remains a black shining porous body, termed Charcoal. This consists principally of a peculiar inflammable matter, which burns in atmospheric air, forming an acid, the Carbonic; but there likewise remains after this combustion a small quantity of saline and earthy matter, which the charcoal contained. This peculiar inflammable matter, which is the principal part of charcoal, and which, mixed with the small portion of foreign substances, forms indeed its entire substance, is termed *Carbon*, in the language of the new nomenclature. It is an abundant principle both in vegetable and animal substances, and is the residuum which they afford when decomposed by heat.

This substance was supposed in the modern system to be simple; but late experiments have shewn that it is not perfectly so, but is rather an inflammable body, in a state of imperfect oxydation.

tion. It had been known for some time, that the diamond is inflammable; it had even been ascertained by the experiments of Lavoisier and Ten-
nent, that by combustion it produces an acid, precisely the same as that formed by the burning of charcoal. At length Morveau discovered, by a series of experiments, that the diamond is, properly speaking, pure carbon, the simple inflammable base of the carbonic acid; and that charcoal, in its purest state, or when most free from accidental mixture, is this simple substance, combined with a portion of oxygen, less than that necessary to form the carbonic acid. This he shewed by proving, that a much greater quantity of this acid is formed from the combustion of a certain weight of diamond than from the same weight of charcoal; 28 parts of the latter combining with 72 of oxygen, to form 100 parts of the acid; while 17.8 of diamond combine with not less than 82.1 of oxygen to form this quantity. As both afford the same product by oxygenation, and as they differ only in requiring different quantities of oxygen to form it, it is evident, that the one must differ from the other in containing a portion of oxygen;—that diamond is the simple base, of which charcoal is the oxyd.

Morveau

Morveau likewise discovered, that there are some substances in intermediate degrees of oxydation between diamond and wood charcoal. The substance termed Plumbago, and several fossil substances known by the name of Incombustible Coal, are of this kind.

DIAMOND.—This substance is distinguished from every other, by its eminent lustre, transparency, and hardness. It is found crystallized, generally colourless, but likewise not unfrequently of various colours. Its specific gravity is from 3.44 to 3.55. It is not acted on by any of the acids, nor indeed by almost any chemical agent; oxygen excepted at a high temperature. When placed in oxygen gas, and exposed to the solar rays concentrated by a powerful lens, its colour first becomes dull, and its surface is sensibly blackened,—changes owing to partial oxydation. When the application of the light is continued, the diamond at length inflames, but faintly; nor is a sufficient quantity of caloric extricated to keep up the temperature requisite to its combustion; it is therefore necessary to continue the application of the solar light collected by the lens. Rather more than four parts of oxygen are requisite for the saturation

uration of the diamond, and five parts of carbonic acid are produced.

PLUMBAGO, or GRAPHITE, usually known by the name of Black Lead, is of a black colour, foliated texture, soft, and somewhat unctuous to the touch. It is not altered by exposure to air or water, neither is it acted on by any of the acids. It is likewise so unalterable by fire, as to be used in making crucibles and furnaces. If it be kept, however, in long ignition in an intense heat, it suffers a gradual combustion, yielding carbonic acid, and affording a residuum of oxyd of iron. It can likewise be deflagrated with nitrat of potash, and affords the same products. Scheele even observed, that it requires double the quantity of nitrat of potash for its deflagration that wood charcoal does.

From this analysis of plumbago, it was considered, in the antiphlogistian system, as a compound of carbon and iron. Morveau has shewn, that by oxygenation it affords more carbonic acid than an equal weight of charcoal does ; it therefore contains less oxygen, and may be considered as diamond in its first state of oxydation. The
iron

iron does not seem to be very essential to its constitution, and is never in a considerable proportion.

The substances termed Incombustible Coal, are similar to plumbago in their difficulty of burning; and, as Merveau has ascertained, in requiring a larger quantity of oxygen than charcoal does, for their saturation. The charcoal obtained from the decomposition of animal matter by heat in close vessels, is scarcely capable of combining with oxygen, but at a very high temperature, and even coal when it has been coked, or exposed to a strong heat without the free access of air, is not so easily kindled as common charcoal. These substances, therefore, probably differ from charcoal in being less-oxydated, whence they have the property of requiring a higher temperature for their combustion; carbon, like azot, being rendered by a partial oxydation more susceptible of combining with a larger proportion of oxygen.

CHARCOAL, or Oxyd of Carbon, is obtained, as has been observed, from the combustion of wood, conducted in such a manner that the free access of the air is not permitted. The constituent principles of the wood are disengaged in new combinations, and the charcoal is the residuum,

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It contains various earthy and metallic substances; these are not essential to its composition, nor are they in any considerable proportion, seldom amounting to more than a 200th part of its weight. By certain processes charcoal may even be obtained nearly free from them. As this substance is in an oxydated state, it is probable that in the process by which it is obtained, the carbon of the vegetable matter has combined with the oxygen either of that matter, or with that of the atmospheric air.

Charcoal is solid, brittle and sonorous, tasteless and inodorous, and perfectly black. It is extremely porous, and is, apparently from this porosity, capable of absorbing large quantities of the gases, without suffering any change in its properties. Water or atmospheric air produce no change in it at a low temperature, and it is not altered by any degree of heat applied to it in close vessels.

But when heated to the temperature of ignition in contact with atmospheric air, it burns, with a red or a white light, according to the rapidity of the combustion, and with the extrication of a large quantity of caloric. In oxygen gas, its combustion is much more vivid, and, if the gas is pure,

pure, the whole of it is consumed. The product of this combustion is an acid, the same with that formed in the combustion of the diamond, as it is the product of the full saturation of carbon with oxygen.

CARBONIC ACID.

This acid contains in the 100 parts, 72 of oxygen and 28 of charcoal; charcoal, however, itself contains a quantity of oxygen: the exact proportions, therefore, of its simple principles, as ascertained by Morveau, are 17.88 of pure carbon, and 82.12 of oxygen. Besides this mode of obtaining it by the direct combination of its elements, it is abundantly produced in the combustion of fuel, wood, and vegetable matter of every kind,—in the fermentation of vegetable substances, and in the decomposition of animal matter by putrefaction or heat.

The existence and properties of this acid were discovered by Dr. Black, who named it Fixed Air, as he found it to be fixed in, or combined with, a number of substances, and as, when freed

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from these combinations, it assumes the aerial form. It exists in abundance in nature. In its aerial state, it is found in caverns and mines, and it is present in the atmosphere in inconsiderable proportion : — in a state of combination, it exists in great quantity in marl, chalk, limestone, and marble, these being compounds of it with lime. It is a constituent principle of many mineral waters, to which it communicates pungency and their sparkling quality.

To obtain this acid, for experiment, any quantity of chalk, limestone, or marble, may be exposed to a strong heat, when it is expelled; or sulphuric acid diluted with 3 parts of water may be poured upon any of them, it immediately combines with the lime, which is one of the constituent principles, and the other, the carbonic acid, is disengaged.

Carbonic acid gas has a specific gravity to that of atmospheric air as 1500 to 1000 : — it is incapable of supporting combustion, and proves immediately fatal to life : — water absorbs about an equal bulk of it : — the pure gas, or this watery solution of it reddens the vegetable colours, and has all the general properties of acids, though

though in a degree much less considerable than many of the other acids.

Carbonic acid combines with the alkalis and earths, forming neutral salts. As its acid powers are comparatively weak, so the changes which it occasions in these bases by combining with them are in general inconsiderable. The alkalis still retain their peculiar taste and acrimony; they change the vegetable colours to a green, and possess indeed all their peculiar properties, only in a less degree. The changes produced in the earths are rather more considerable, but still several of the original properties are retained. Before the time of Dr. Black, these compounds were considered as modifications of the alkalis and earths, and were termed Mild, to distinguish them from the others which were named Caustic. He shewed, that they contain carbonic acid, and Bergman demonstrated that they are neutral salts,

The distinguishing character of this order of neutral salts is their property of effervescing on being mixed with acids: this is owing to the attraction of the carbonic acid to the base being so weak, that it is separated by the acid added: in the moment of its separation it assumes the gaseous form,
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and, rising through the liquor, produces the appearance termed Effervescence.

CARBONAT OF POTASH. — Potash, in the processes by which it is prepared, is always combined with a quantity of carbonic acid. This, however, is not sufficient to saturate it; it does not form, therefore, a perfect neutral salt, but a compound, with an excess of alkali, which may be termed the Sub-carbonat of Potash. It is the substance that has been known to chemists under the names of Mild Vegetable Alkali, Salt of Tartar, &c. It is usually in the form of a coarse powder, perfectly white, its taste is acrid, and it possesses some causticity, though not so much as pure potash; it is deliquescent, is soluble in half its weight of water, combines with oils, and is decomposed by acids, or exposure to heat, its acid being driven off. It consists of 60 parts of potash, 30 of carbonic acid, and 6 of water.

The neutral carbonat of potash possesses properties different from those of the sub-carbonat. It is capable of crystallizing; its crystals do not deliquesce on exposure to the air, but are rather efflorescent; they require for their solution four times their weight of water at a mean temperature.

ture. This salt though it has little of the alkaline taste or acrimony, still changes the vegetable colours to a green. It consists of 41 of potash, 43 of carbonic acid and 16 of water. It is decomposed by heat, by all the acids, which combine with its base, and by lime, barytes, and strontites, which attract its acid.

This neutral salt may likewise be *super-saturated* with carbonic acid, by introducing the acid gas into a solution of the alkali in water. The solution acquires a pungent acidulous taste, and is used in medicine as being more pleasant and mild than the alkali in any other form.

CARBONAT OF SODA. — Soda, in the state in which it is usually prepared by the incineration of marine plants, is combined with carbonic acid. This carbonat of soda, freed by solution from the impurities with which it is mixed, crystallizes in rhomboidal crystals; these effloresce on exposure to the air; they are soluble in twice their weight of water, at a mean temperature, and in an equal weight of boiling water. The taste of this salt is alkaline, but with little acrimony; it changes the vegetable colours to a green; it suffers decompositions similar to those of the carbonat

bonat of potash, and is further decomposed by pure potash which attracts its acid. When fully saturated with acid and crystallized, it consists of 21.58 parts of soda, 14.42 acid, and 64 water.

CARBONAT OF AMMONIA.—This salt may be obtained by the direct combination of its principles, ammonia and carbonic acid gases combining with facility, and forming a concrete salt. It is usually prepared by exposing to a moderate heat equal parts of dried carbonat of lime, and muriat of ammonia in powder; the lime attracts the muriatic acid of the muriat of ammonia, and the ammonia combines with the carbonic acid of the carbonat of lime; the carbonat of ammonia formed is sublimed by the heat that is applied. Another process to obtain the watery solution of it is, to expose to heat equal parts of muriat of ammonia and sub-carbonat of potash, with two parts of water; the ammonia attracts the carbonic acid of the latter salt, and is volatilised with the aqueous vapour.

Carbonat of Ammonia is a concrete salt, so volatile, that it exhales at a natural temperature; it retains the pungent ammoniacal odour and taste, is slightly caustic, and is capable of changing the vegetable

vegetable colours to a green. It is soluble in twice its weight of water at a mean temperature, and in less than its own weight of boiling water, and is capable of being crystallized. It is decomposed by the two fixed alkalis, by several of the earths, and by nearly all the acids. According to Bergman, it consists of 43 parts of alkali, 45 of acid, and 12 of water. Its composition, however, Mr. Davy observes, is various, according to the temperature at which it is formed; so much so, that the proportion of ammonia varies from 20 to 50 parts in the 100.

Carbonic acid scarcely exerts any action on the metals, or on inflammable substances, owing to the strong attraction which exists between its principles. From the strength of this attraction, it seemed scarcely possible to decompose it, as no known substance has a stronger attraction to oxygen than carbon. This decomposition, however, has been effected by the aid of concurrent affinities. A small quantity of phosphorus is exposed to a red heat with carbonat of lime; a quantity of carbonaceous matter mixed with phosphat of lime, is obtained; the carbonic acid being decomposed by the concurrent affinities of phosphorus for oxygen, and of phosphoric acid for lime.

lime. Mr. Cruickshank has shewn, that it is also partially de-oxydated when carbonat of lime is heated with filings of iron, gaseous oxyd of carbon being produced.

CARBONATED HYDROGEN.

CARBON is capable of combining with hydrogen, and forms a compound gas, termed Hydrocarbonate, or Carbonated Hydrogen. There are several gases of this kind, obtained by different processes, which differ in their properties and in the proportions of their constituent principles.

If charcoal be heated to redness, and water be dropped slowly upon it, it is decomposed; one part of the carbon combining with its oxygen, another with its hydrogen, carbonic acid and hydrocarbonate are formed. These pass off in the state of gas mixed together: the carbonic acid may be abstracted by washing the mixed gas with lime water, and the hydrocarbonate gas is thus obtained pure.

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This gas has a specific gravity greater than that of pure hydrogen; it is to that of atmospheric air as 11 to 23; it is less inflammable, burns with a blue flame, and does not explode, even when mixed with atmospheric air, previous to its inflammation. It is more immediately fatal to animal life than the greater number of the gases. It has the singular property of communicating to the blood and muscles a florid red hue.

The products of the combustion of this gas are water and carbonic acid. Mr. Cruickshank, from ascertaining the quantities of these products, and the quantity of oxygen consumed, supposes it to consist of 4 parts of carbon, 1.3 of hydrogen, and 9 of water. It may, however, be rather the elements of water, than water itself, which it contains; and in this case it will be a ternary compound of carbon, hydrogen, and oxygen.

In the decomposition of alcohol, ether, or camphor, by passing these substances in the state of vapour through an ignited tube, other gases, somewhat different from the former, are produced. They are heavier; their specific gravity, according to the experiments of Cruickshank, being to

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that

that of atmospheric air, as 15.5 to 23.5; and they contain a considerably larger proportion of carbon. In their properties they are very similar to the former.

There are still other two gases different from these, one produced by exposing to heat mixtures of metallic oxyds with charcoal, the other from a mixture of filings of iron with the carbonats of lime or barytes. These are very similar to each other, the one being only a little heavier; their specific gravity is nearly the same as atmospheric air, being as 22 to 23; hence they are nearly twice as heavy as the hydrocarbonate, from the decomposition of water by charcoal: they burn with a blue lambent flame, and do not explode when previously mixed with atmospheric air. Mr. Cruickshank has clearly shewn, that they differ from the preceding gases in containing a larger proportion of oxygen, as by the addition of a small portion of oxygen they are converted into carbonic acid: they are indeed nearly pure gaseous oxyds of carbon; a small portion of hydrogen seems, however, to enter into their composition, and they may be considered as ternary compounds of that element with carbon and hydrogen.*

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* Nicolson's Journal, Vol. V.

Sect. II. — — *SULPHUR.*

SULPHUR is a simple inflammable substance, found in abundance in nature in various states. Native sulphur is either crystallized, or in compact masses, and in both forms is found in the neighbourhood of volcanoes. It likewise exists in large quantities, combined with some of the metals; and from some of these, particularly from the combination of it with iron, it is likewise extracted for the purposes of commerce. The sulphur obtained from either of these sources, is freed by sublimation from the substances with which it is naturally mixed or combined. Sulphur is also contained in inconsiderable quantity in several vegetable and animal products.

Sulphur is a solid brittle substance, tasteless and inodorous, except when heated or rubbed, when it emits a slightly foetid smell. Its specific gravity is 199. It is insoluble in water. It melts at 223 of Fahrenheit, and at the same temperature is volatilised. At 300 it burns in atmospheric

spheric air with a blue flame, and the emission of very pungent suffocating fumes. At a higher temperature it burns with a white flame; and in oxygen gas, its combustion is vivid.

Sulphur combines with oxygen in two proportions, forming compounds of an acid nature, differing in their properties from each other. According to the principles of the new nomenclature, the acid with the larger proportion of oxygen is termed Sulphuric; that with the less proportion, Sulphureous. The acid powers of the former are much more considerable than those of the latter.

SULPHURIC ACID.

This acid is formed during the combustion of sulphur. When the combustion is carried on in atmospheric air, the oxydation is imperfect, and a considerable quantity of sulphureous acid is formed. In the manufacture, therefore, of the sulphuric acid, the sulphur is mixed with from one-eighth to one-twelfth of nitrat of potash; the mixture is kindled, and placed in a large leaden chamber; by the slow combustion of the sulphur, sulphuric acid

acid is formed, which is absorbed by water placed in the bottom of the chamber. This liquor, after a certain degree of impregnation, is exposed to heat in glass retorts, so as to deprive the acid of the superfluous water, the sulphureous acid, and nitrous gas, with which it is mixed. It is not perfectly pure, but contains small quantities of sulphat of lead, and sulphat of potash, from which it may be freed by distillation, or, in a great measure, by dilution with water. Besides this mode of obtaining this acid, it was formerly procured by decomposing by heat the green vitriol of commerce, or sulphat of iron; and hence was usually named Vitriolic Acid.

Sulphuric acid, in its usual degree of concentration, is heavier than any other acid, its specific gravity being to that of water as 1850 to 1000; it may be concentrated so far as to have a specific gravity equal to 2000. Even in this state, it contains a quantity of water, according to the experiments of Mr. Kirwan, not less than 10.7 parts in the 100. It has been obtained in a concrete state; but this seems to depend on its containing a quantity of sulphureous acid, which gives it the property of congelation. The pure acid, apart from the water which it always contains,

contains, is supposed by Berthollet to consist of 36.8 of oxygen, and 63.2 of sulphur.

Sulphuric acid, in its usual fluid state, is colourless and transparent, of an oily consistence, inodorous, extremely caustic, so as to destroy any animal or vegetable matter on which it falls; it reddens deeply the vegetable colours, and possesses in an eminent degree the general properties of acids. At a temperature somewhat inferior to 600 of Fahrenheit, it is volatilised, without suffering any change. It has a strong attraction to water, and combines with it in every proportion: A considerable rise of temperature is produced by their combination from change of capacity.

Sulphuric acid is not altered by oxygen or azot; hydrogen at a high temperature decomposes it by attracting its oxygen. Nitrous gas is absorbed by it; it combines with nitrous acid, and forms a compound which dissolves silver, but scarcely any other metal. It is decomposed by a number of inflammable substances, which attract its oxygen. If poured on any vegetable or animal matter, a decomposition of this kind takes place, and a quantity of carbon is evolved, which gives the acid a brown or black colour. It is also capable

capable of oxydating and dissolving a number of the metals, either affording to them part of its oxygen, or, by a disposing affinity, enabling the metal to decompose the water which is present.

Sulphuric acid combines with the alkalis, and forms neutral salts termed Sulphats. It has in general a stronger attraction to them than any of the other acids have; and hence, the salts which it forms are not easily decomposed. Barytes and strontites are capable of decomposing them, by exerting a stronger attraction to their acid. When heated with charcoal, their acid is decomposed by its oxygen being attracted by the carbon.

SULPHAT OF POTASH. — This salt is generally prepared by the direct combination of its principles, or by decomposing, by sulphuric acid, those salts which have potash for their base. Its crystals are not deliquescent; it is soluble in 12 parts of water at a mean temperature, and in 4 parts of boiling water; is fused and volatilised by heat, without decomposition. It consists, according to Bergman, of 40 parts of acid, 52 of alkali and 8 of water. Kirwan states the proportions

proportions of it, when dried, at 45.2 of acid, and 54.8 of alkali.

This salt can be decomposed only by barytes and strontites, by a single attraction; it may be likewise decomposed by a number of neutral salts by double elective attraction, and by several of the acids by means of what has been termed reciprocal affinity. If nitric acid be digested upon part of it, it is decomposed, and a quantity of nitrat of potash is formed. Not more than one third of the salt can be decomposed, whatever quantity of the nitric acid may be used. The decomposition is effected by conspiring affinities, by that of the nitric acid for potash, and of sulphat of potash for an excess of sulphuric acid; the former would be ineffectual, but is promoted by the latter: the products are nitrat of potash, and acidulous sulphat of potash. Sulphat of potash is likewise decomposed by heating it with charcoal, the carbon attracts its oxygen, and the potash remains combined with the sulphur.

The acidulous sulphat of potash has a sour taste, reddens the vegetable colours, and is more soluble in water than the neutral salt.

SULPHAT OF SODA.—This salt exists in considerable quantity in salt springs and lakes, and is even found at the surface of the earth. It is prepared artificially by decomposing common sea salt, or muriat of soda, by sulphuric acid, this acid uniting with the soda of the salt, and forming sulphat of soda, which is obtained by solution and crystallization; its crystals are soluble in three times their weight of water at a mean temperature, and in rather less than an equal weight of boiling water; they are efflorescent, undergo the watery fusion, by heat, but suffer no decomposition. They consist, according to Kirwan, of 18.48 of alkali, 23.52 of acid, and 58 of water of crystallization.

This salt is decomposed by potash, which attracts its acid, and suffers partial decomposition from the nitric and muriatic acids.

SULPHAT OF AMMONIA.—This salt has been found in the neighbourhood of volcanoes, and it may likewise be obtained from the soot of wood or coal. It may also be prepared by the direct combination of its principles, or by decomposing ammoniacal salts by sulphuric acid. It is

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soluble in twice its weight of water at a mean temperature, and in an equal weight of boiling water. It is easily volatilized by heat, part of its ammonia, however, being expelled. In its crystallized state it consists, according to Kirwan, of 14.24 of ammonia, 54.66 of acid, and 31.1 of water. It is decomposed by the two fixed alkalis, and by several of the earths, which attract its acid.

SULPHUROUS ACID.

THIS acid is formed during the burning of sulphur in atmospheric air; but for the purposes of experiment, it is most easily obtained by decomposing partially the sulphuric acid, by any substance capable of attracting its oxygen. If two parts of acid be exposed to a moderate heat, with one part of quicksilver, such a decomposition is effected, and sulphurous acid disengaged.

This acid exists in the state of permanent gas, except at a very low temperature, and under a strong pressure, by which it has been reduced to the fluid state. Its specific gravity is nearly double that of atmospheric air; it has a strong suffocating

suffocating odour, and proves speedily fatal to animal life; it is not inflammable, and extinguishes combustion. It is absorbed by water, the solution retaining the pungent smell of the gas. The acid powers of this compound are not considerable; it does not redden the vegetable colours, but renders them white; it exerts little action on the metals, and has a weak attraction to the alkalis or earths. Sulphureous acid gas, mixed with oxygen, and kept over water, is gradually converted into sulphuric acid; the same combination takes place more rapidly by passing the mixture through an ignited tube. By the same means hydrogen may be made to decompose it; and carbon, at the temperature of ignition, likewise attracts its oxygen.

The salts formed by the sulphureous acid are termed Sulphites. Their taste is sulphureous; they are decomposed by the greater number of acids, which combine with their bases. By exposure to the atmosphere, or any substance capable of affording them oxygen, they are converted into sulphates.

SULPHITE OF POTASH. — Sulphureous acid unites with facility with potash. The salt can be obtained

obtained in white transparent crystals; it is soluble in an equal weight of water at a mean temperature, and in a less quantity of hot water. Exposed to heat, part of its acid, along with a portion of sulphur, are expelled. It is decomposed by the greater number of the acids, the sulphureous acid being disengaged. Some acids, which can communicate oxygen to it, convert it into sulphat of potash. It is also decomposed, not only by barytes, but by lime, which attracts its acid.

SULPHITE OF SODA. — This salt when crystallized is white and transparent; its taste is cool; it is soluble in 4 parts of water at a mean temperature. Exposed to heat, it first undergoes the watery fusion, and is then decomposed. From the chemical agents it suffers decompositions similar to those of the sulphite of potash. From the experiments of Vauquelin, its crystals appear to consist of 18.8 parts of soda, 31.2 of acid, and 50 of water.

SULPHITE OF AMMONIA. — Sulphureous acid and ammonia, when in the state of gas, combine with facility, and form a concrete salt. This salt requires less than its own weight of boiling water for its solution; the solution crystallizes on cooling; these crystals are fused and volatilized by heat

heat without decomposition. Exposed to the air, it absorbs humidity, and gradually attracts oxygen. It contains 29 of ammonia, 60 of acid, and 11 of water.

SULPHURATED HYDROGEN.---ALKALINE
SULPHURETS.

SULPHUR is capable of combining with hydrogen, and forms a compound termed Sulphurated Hydrogen, which exists in the state of permanent gas. This gas, for the purpose of experiment, is most easily obtained from the compounds which sulphur forms with the alkalis, and these may therefore first be noticed.

If a quantity of potash or soda be fused with an equal weight of sulphur, a chemical compound is formed, of a dark red colour: this is the Sulphuret of Potash or Soda. While dry, it is inodorous; if moistened, it emits a very foetid smell, which still remains when it is entirely dissolved in water; if to this solution any acid be added, a quantity of gas is disengaged, having the same foetid odour, and sulphur is precipitated.

Berthollet

Berthollet first satisfactorily explained the nature of these changes. The dry mass obtained by fusing the sulphur and alkali, is a chemical compound of these two substances; when water is added, part of it is decomposed, the alkali, by a dissolving affinity, enabling the sulphur, even at a low temperature, to attract part of its oxygen, and form sulphuric acid: the portion of hydrogen thus separated combines with another portion of the sulphur, and forms sulphurated hydrogen. It is the presence of this compound that gives the solution the foetid odour: it is retained by its attraction to the alkali or alkaline sulphuret; but when an acid is added, this combines with the whole of the alkali that is present; the sulphur that was previously combined with it is precipitated, and the sulphurated hydrogen is disengaged in the gaseous form.

Sulphurated hydrogen is also produced by decomposing some of the metallic sulphurets by muriatic acid, and it is formed by heating sulphur in hydrogen gas, by means of the concentrated solar light. It is distinguished by its very foetid smell: its specific gravity is to that of atmospheric air as 1106 to 1000: it extinguishes combustion, and is incapable of supporting life: water absorbs about
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one half its bulk of it ; the solution has a foetid smell and nauseous taste ; and it, as well as the gas, has the property of reddening several of the vegetable colours.

Sulphurated hydrogen possesses some inflammability : when mixed with atmospheric air, it burns with a blue or greenish flame, and without detonation ; when mixed with an equal part of oxygen, it detonates on the contact of an ignited body, sulphureous acid being formed ; a mixture of it with an equal measure of nitrous gas burns with a yellow or green lambent flame, and some sulphur is separated ; with a larger quantity of nitrous gas, the sulphurated hydrogen is even rapidly decomposed without inflammation, its hydrogen combining with part of the oxygen of the nitrous gas, so as to convert it into nitrous oxyd, and sulphur being deposited. A similar decomposition is produced in it by sulphureous acid gas, and even by sulphuric or nitric acids. The electric spark also precipitates its sulphur. From these decompositions it has been inferred, that the quantity of sulphur it contains amounts to one eighth part.

Sulphurated

Sulphurated hydrogen combines with facility with the alkalis and earths. These compounds are soluble in water, are colourless while the atmospheric air is excluded, but become yellow when it is admitted : they are decomposed by the acids, which disengage the sulphurated hydrogen. Berthollet considers these compounds as analogous to neutral salts, and sulphurated hydrogen itself as of the nature of an acid, from its properties of forming these combinations, and of reddening the vegetable colours.

These compounds are termed by Berthollet Hydro-Sulphurets : they are capable of combining with an addition of sulphur ; and such compounds he terms Hydrogenated Sulphurets. *Sulphurets* are compounds of sulphur with other substances, with alkalis, earths, or metals ; *Hydro-sulphurets* are compounds of sulphurated hydrogen ; and *Hydrogenated sulphurets* are compounds of hydro-sulphurets, with an additional proportion of sulphur. Of these compounds, it remains only to notice the properties of the alkaline sulphurets.

SULPHURET OF POTASH. — This compound is obtained by fusing equal parts of sulphur and potash. It is of a red colour; is very fusible; is inodorous while it remains solid:—if exposed to the air, it attracts humidity, and acquires a foetid smell, which is also produced when it is dissolved in water, owing, as has been observed, to the production of fulphurated hydrogen.

When the solution of sulphuret of potash is exposed to atmospheric air, it soon attracts its oxygen,—its colour becomes fainter,—it at length nearly disappears, and nothing is found in the solution but sulphat of potash. These phenomena are owing to the absorption of the oxygen of the air, by the hydrogen of the fulphurated hydrogen contained in the solution, and the oxygenation of the sulphur from its decomposing the water.

From this quality, the liquid sulphuret of potash has been used as a eudiometer, and it has the advantage of completely absorbing the oxygen; nor is there any degree of fallacy in its operation; it is only inconvenient from the slowness with which it is performed. Morveau has proposed

to obviate this inconvenience by using the solid sulphuret slightly moistened, and applying heat, by which the absorption of oxygen is rendered more rapid.

Sulphuret of potash is decomposed by the acids; they combine with its alkali, and precipitate its sulphur. This sulphur, from its state of aggregation, is of a lighter colour than usual, and in pharmacy has been termed *lac fulphuris*.

SULPHURET OF SODA has properties precisely the same with those of the sulphuret of potash, and suffers similar decompositions.

SULPHURET OF AMMONIA has properties somewhat singular. It cannot be formed by digesting ammonia or sulphur, but only by presenting the former in its nascent state to the latter. Four parts of lime are mixed with two of muriat of ammonia and one of sulphur, in a retort connected with receivers, and heat is applied; the lime attracts the muriatic acid; the ammonia is disengaged, and combines with the sulphur; and the sulphuret of ammonia is disengaged in the state of gas. It may be absorbed by water placed in the receivers;—a red coloured liquor is formed, which

which has a foetid smell, and emits copious fumes. It is decomposed in the same manner as the other alkaline fulphurets.

Sett. III. — — PHOSPHORUS.

PHOSPHORUS is a simple substance, which, as it combines with oxygen at the lowest natural temperature, cannot exist pure in nature. The product of this combination, a peculiar acid, is found in abundance in nature. In the mineral kingdom it exists combined with several of the metals and earths; and it is a component part of many animal products.

The pure phosphorus is obtained by various processes. If urine be evaporated to dryness, a mass is obtained, containing, among other saline substances, phosphat of soda and phosphat of ammonia: if this mass be mixed with charcoal, and exposed in a retort to a strong heat, the latter salt is decomposed, the oxygen of its acid is attracted by the carbon of the charcoal; the phosphorus is thus separated, and is sublimed by the heat applied.

plied. The product of phosphorus may be increased by adding to the mixture any of the salts of lead, these decomposing the phosphat of soda likewise; or the urine may, without evaporation, be decomposed by a solution of acetite of lead, and the precipitate mixed with charcoal, and exposed to heat. But even in this case the product is lessened, from the phosphorus being in part attracted by the lead.

Another process is generally followed, as being less disagreeable. The solid matter of bones consists of phosphat of lime; they are burnt to whiteness, powdered, and digested with rather less than one part of sulphuric acid, diluted with 12 parts of water. The acid partially decomposes the phosphat of lime, and an acidulous phosphat of lime is obtained: this is either evaporated to the consistence of syrup, made into a mass with charcoal powder, and exposed to a sufficient heat in a close vessel; or, what is a preferable method, the phosphoric acid is saturated with ammonia, and the phosphat of ammonia, thus formed, being mixed with 1-3d part of charcoal, is exposed to heat in a glazed earthen retort: the carbon attracts the oxygen of the phosphoric acid of the salt, and the phosphorus distils over. As first obtained, it is impure,

pure, from the mixture of carbonaceous matter with it; but it may be purified by inclosing it in a piece of fine leather, plunging it in hot water, so as to melt the phosphorus, and pressing it through.

Phosphorus, thus purified, is of the consistence of wax; is colourless and transparent; has a specific gravity equal to 1.914. It melts in water at the temperature of 99° ; at 219° it is volatilised; at 554 it boils in close vessels.

When phosphorus is exposed to atmospheric air, it emits fumes of a foetid smell: these are the product of its slow combustion, and in a dark place this is perceptible from its luminous appearance. At the temperature of 100° , its combustion is more rapid; and at 160° , it burns with a bright flame, and with the emission of a large quantity of caloric. Its combustion in oxygen gas is extremely vivid, a very large quantity of light being emitted. It is singular, that though in atmospheric air it suffers a slow combustion, even at low natural temperatures, yet it does not do so in pure oxygen gas, but requires to be considerably heated to cause it to burn. This fact, which chemists for some time found

found it difficult to explain, has been proved to be owing to phosphorus being soluble in azotic gas, and, when dissolved by it, combining with oxygen at a much lower temperature than it can do when in its pure concrete state. In atmospheric air, therefore, its slow combustion is owing to the azot dissolving it, and presenting it to the oxygen. Hence also it appears luminous in azotic gas, because that gas is seldom perfectly free from oxygen. Hydrogen has been found to have the same effect upon it as azot.

Phosphorus, by its power of combining with oxygen with so much facility, affords a very convenient eudiometer. The slow combustion of it is preferable, for this purpose, to the more rapid produced by raising the temperature, as no management is necessary on account of the expansion of the air, and as a certain indication of the completion of the process is obtained by the phosphorus ceasing to be surrounded with a white cloud, or to be luminous in the dark. It must be performed over water. In the eudiometer of Berthollet, a piece of phosphorus attached to a glass rod is placed in a tube filled with the air to be tried, and inverted in water; the diminution of volume is estimated by measuring the air, before and after
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the process, in a graduated tube. In the eudiometer of Gren, a piece of phosphorus fixed upon two or three needles passed through a cork, is placed at the orifice of a graduated tube inverted in water, and filled with the air. As the oxygen is absorbed, the water rises, with the cork swimming on its surface, and the phosphorus is thus presented to the air. Berthollet has ascertained, that the bulk of the residual azotic gas is increased one fortieth by its dissolving a portion of the phosphorus; and, of course, this correction requires to be made.

Phosphorus is oxygenated by nitrous gas, nitric, sulphuric, and oxygenated muriatic acids.

The products of the oxygenation of phosphorus are two acids, the phosphoric and phosphorous; the one having a larger, the other a less proportion of oxygen. The latter is the immediate product of the slow combustion of phosphorus: by exposure to the atmosphere, it absorbs oxygen, and is converted into the other; or if it be exposed to a moderate heat, it emits white fumes, and the phosphoric acid remains.

PHOSPHORIC ACID.

THIS acid is capable of existing in the solid form, and, by a strong heat, it may even be formed into a perfect glass. It is very deliquescent, and soluble in water: its saturated solution is of an oily consistence: it is inodorous, and possesses no volatility. It is not decomposed by heat. Exposed to a high temperature with charcoal, its oxygen is abstracted, and phosphorus obtained. According to the experiments of Lavoisier, it consists of 100 parts of phosphorus, united with 154 of oxygen.

Phosphoric acid combines with the three alkalis, forming salts, termed Phosphats. They are decomposed, in the humid way, by the sulphuric, nitric, and muriatic acids; but in the dry way, at a high temperature, the order of attractions is reversed, the phosphoric being able to decompose the salts which are formed by these acids, owing probably to its great fixity.

PHOSPHAT OF POTASH is a salt which has been little examined. It can scarcely be crystallised,
but

but forms, by evaporation of its solution, a gelatinous mass, which is deliquescent. By the application of a strong heat, it is fused into a glass. Barytes and lime decompose it, by attracting its acid. It suffers no decomposition by being heated with charcoal.

PHOSPHAT OF SODA. — This salt, which is used in medicine and the arts, is prepared, by adding to the solution of the acidulous phosphat of lime, obtained by decomposing burnt bones by sulphuric acid, a solution of carbonat of soda: the soda combines with the excess of phosphoric acid, and the phosphat of soda is obtained by evaporation, in regular rhomboidal crystals, which have generally a slight excess of alkali. These crystals are efflorescent. They are soluble in 3 parts of cold, and in half that quantity of boiling water. They are vitrified by heat, and promote greatly the fusion of the earths and metallic oxyds. This salt is decomposed by lime and barytes, and suffers no change by being heated with charcoal.

PHOSPHAT OF AMMONIA. — This salt exists in the urine of carnivorous animals in considerable
R r quantity.

quantity. It is obtained pure by the direct combination of its principles. It is soluble in 4 parts of cold, and in a less quantity of hot water ; — is crystallizable. By exposure to heat, it is first fused, and then decomposed, its ammonia being expelled ; and when heated with charcoal, the oxygen of its acid is abstracted, and phosphorus formed. It is decomposed by the two fixed alkalis, and by several of the earths.

The phosphorous acid unites with the alkalis and earths, forming salts, termed Phosphites.— They are similar in their properties to the phosphats, but are characterised by appearing luminous when heated, and by affording a small quantity of phosphorus by distillation. PHOSPHITE OF POTASH is soluble in water, and crystallizable ; it melts by heat, with the appearance of a phosphorescent light ; is decomposed by lime and barytes, and by several of the acids. The PHOSPHITE OF SODA has properties very similar, but is more soluble in water. The PHOSPHITE OF AMMONIA is distinguished by a strong penetrating taste ; when heated by the blow-pipe, it is decomposed, and phosphorated hydrogen is disengaged ; it is likewise decomposed by heat in close vessels, the ammonia

monia being expelled, holding a small quantity of phosphorus in solution.

The phosphoric and phosphorous acids act feebly upon the metals, but combine with the metallic oxyds.

PHOSPHORATED HYDROGEN.

This compound of phosphorus and hydrogen exists in a state of gas. It is obtained by combining the phosphorus with some substance which, by a disposing affinity, may enable it to decompose water. One part of phosphorus is heated with 12 parts of a solution of pure potash; it combines with the alkali, and this compound decomposes part of the water; one part of the phosphorus attracts its oxygen, and another part of it combines with the hydrogen disengaged, and forms the phosphorated hydrogen, which passes off in the state of gas.

The characteristic property of this gas is, its inflaming on coming into contact with atmospheric air; the products of the combustion are aqueous vapour

vapour and phosphoric acid, which form a light white cloud, that ascends in a horizontal circle. In oxygen gas, its combustion is instantaneous and violent, attended with the emission of a large quantity of caloric. The smell of this gas is foetid and putrid; it is not absorbed by water, but is slowly decomposed by standing over it, the oxygen of the atmospheric air contained in the water attracting its phosphorus. It does not combine with the alkalis.

Another mode of obtaining phosphorated hydrogen is to combine phosphorus with lime, by exposing to heat, in a glass tube, a piece of phosphorus, over which a quantity of lime has been pressed. A phosphuret of lime is formed; this, when thrown into water, immediately decomposes it; and the hydrogen disengaged, dissolving part of the phosphorus, forms phosphorated hydrogen, which escapes from the surface of the fluid, and inflames.

Phosphorus enters into combination with sulphur, forming a mass more fusible than either of
its

its principles. It does not unite with carbon, but combines with almost all the metals. It is soluble in expressed and volatile oils, and communicates to them a phosphorescent property. It is dissolved also by alcohol and ether.

CHAP.

CHAP. IV.

UNDECOMPOSED ACIDS.

BESIDES the acids resulting from the oxygenation of the simple inflammable substances, there are others which have not hitherto been decomposed. The analogy between these and the other acids is so direct, that there can be little hesitation in considering them as similar compounds of oxygen with unknown bases. It is in this part of our arrangement that they are most properly placed. There are three acids of this kind, the Muriatic, Boracic, and Fluoric.

Sect.



Sett. I. — — MURIATIC ACID.

GIRTANNER supposed that he had discovered the base of this acid to be hydrogen, and that it differed from water only in its degree of oxygenation. This opinion has been amply refuted by the experiments of Henry and Van Mons. Berthollet has lately supposed, that it is a triple compound of hydrogen, azot, and oxygen; but the supposition has not been confirmed by decisive experiments.

Muriatic acid exists in abundance in nature. Combined with soda, it forms common sea salt; it is united with other bases in the water of the ocean, and in mineral springs; and in the earth is found combined with several of the metals. To obtain the pure acid, two parts of sea salt heated, so as to consume any impurities it may contain, are put into a retort, and one part of sulphuric acid is poured upon it. Heat is applied; the sulphuric acid combines with the soda of the sea salt, and the muriatic acid is disengaged.

It

It assumes the state of gas, and is made to pass through water placed in the receivers connected with the retort, by which it is absorbed. This forms the liquid muriatic acid, which is generally of a yellow colour from the presence of iron ; but which may be obtained more pure by a second distillation.

Muriatic acid naturally exists in the form of gas. It is not inflammable---extinguishes combustion,---and proves fatal to life. It has a penetrating smell, and even when mixed with atmospheric air, occasions a sense of suffocation. Its specific gravity is to that of atmospheric air as 5 to 3. It is not acted on by any of the simple gases, but attracts the water they contain. It oxydates several of the metals, and is absorbed by phosphorus, charcoal, oils, and alcohol. By the electric spark its volume is enlarged, owing to the production of hydrogen, from the decomposition of its water.

Muriatic acid gas has a strong attraction to water ; it is rapidly absorbed by it, and in very large quantity, caloric being at the same time evolved. In the common liquid muriatic acid which this solution forms, the water is seldom saturated, when the

the specific gravity is 1.196, it contains, according to the experiments of Mr. Kirwan, 25.28 parts of real acid. It is highly corrosive, reddens deeply the vegetable colours, and possesses all the general acid properties. It usually emits white fumes, which are merely the muriatic acid escaping from it, and condensing, by combining with the humidity of the atmosphere.

Muriatic acid exerts much less action on the inflammables or metals, than the acids hitherto considered, as it cannot afford them oxygen. It can only, by a disposing affinity, enable those metals which have a strong attraction to oxygen, to decompose the water with which it is combined. An evolution of hydrogen, therefore, attends these actions.

It combines with the alkalis, forming salts, termed Muriats. They have, in general, a sharp taste; they suffer decomposition from the sulphuric and nitric acids, these, exerting a stronger attraction to its base; they are not decomposed by heat.

MURIAT OF POTASH is formed by the direct combination of its principles; it has a bitter salt
Sf taste,

taste, is soluble in three parts of cold, and two of boiling water, the latter solution crystallizing on cooling. It is fused by heat, without decomposition. According to Kirwan, it consists of 46 parts of alkali, 36 of acid, and 18 of water. It is decomposed by the sulphuric, and nitric acids which combine with its basis, and by barytes, which attracts its acid.

MURIAT OF SODA is one of the most abundant productions of nature. The water of the ocean owes its saltness to it : it is found in a number of mineral springs, and it forms immense strata in the earth. According as it is obtained from these sources, it is named Sea Salt or Rock Salt. Rock Salt is hard, frequently transparent, and coloured, from the presence of iron. It is dug in large quantities from several mines in Europe. Sea salt is obtained in warm climates, by spontaneous evaporation ; in colder countries, by evaporation from the application of heat ; or sometimes both these methods are employed in the process. It is in general more or less impure, from the intermixture of other salts which the sea water contains. These render it deliquescent, give it a bitter taste, and considerably impair its antiseptic power. Various processes, therefore, are practised to free it

it from them. For chemical purposes, it is most completely purified, by adding to its solution carbonat of soda, as long as any cloudiness is produced, filtering the solution, and evaporating it, so as to cause it to crystallize.

Muriat of Soda has a salt agreeable taste, it is soluble in rather less than 3 parts of water at the temperature of 60, and is not more soluble at any higher temperature, even to 212°. Its solution by spontaneous evaporation affords crystals, which are regular cubes; these neither deliquesce nor effloresce on exposure to the air; they decrepitate on being heated; are fused in an intense heat; and even volatilised without decomposition. They consist of 35 of soda, and nearly 40 of real acid, the remaining 25 parts being mostly water of composition.

This salt is decomposed by the sulphuric and nitric acids, and, in the dry way, by the phosphoric and boracic. It is also decomposed by barytes, and potash. One of the most important practical problems in chemistry is to decompose it so as to obtain its alkali. This has been done by potash, by the oxyds of lead and iron, by sulphuric

phuric acid, and by various other substances; but perhaps no process has yet been discovered, capable of being carried on to much advantage on a large scale.

MURIAT OF AMMONIA.—This salt is the sal-ammoniac of commerce, which has been long used in the arts. It is found native, but for use is always prepared by art, by various indirect processes in which the ammonia, one of its constituent principles, is derived from animal matter; and the muriatic acid from sea salt. It is sublimed in the usual mode of preparing it, and is therefore met with in large, hard, semispherical cakes, with a slight degree of transparency, and having a texture somewhat ductile. It is, however, capable of crystallization. The taste of this salt is acrid: It requires for its solution $3\frac{1}{2}$ parts of water at a medium temperature, and only an equal part of boiling water. It is volatilised by heat, with little or no decomposition. It contains 30 parts of ammonia, 35 of acid, the remaining 35 parts being partly water of crystallization, and partly water of composition. In its sublimed state, it consists of 25 of alkali, 42 of acid, and 32 of water.

Muriat

Muriat of ammonia is decomposed by the sulphuric and nitric acids, which combine with its base, and by the two fixed alkalis and several of the earths, which attract its acid.

OXYGENATED MURIATIC ACID.

MURIATIC ACID is capable of combining with a quantity of oxygen. By this combination, however, its acid powers are not increased, but diminished; it has a less attraction to water; has a styptic, instead of a sour taste; instead of reddening the vegetable colours, it renders them white; and its attractions to the alkalis and earths are much weaker than those of the pure acid. It is evident, that the difference between these two states of this acid, is not analogous to the differences in the other acids, arising from the difference in the degree of their oxygenation; a peculiar nomenclature is therefore used to express it:—the name Oxygenated Muriatic Acid, or, as some have contracted it, Oxy-muriatic Acid, being given to the compound formed by the muriatic acid with oxygen.

This

This combination cannot be effected by mixing together the muriatic acid and oxygen gases, the attraction between their bases not being sufficiently strong to overcome the repulsive force of the caloric in each gas. But the combination is effected with facility, by presenting oxygen in its nascent state to the muriatic acid. This may be done by distilling the acid from any of the metallic oxyds in which the oxygen is not retained by a strong attraction; and it was by this process that Scheele, the discoverer of this acid, obtained it. The black oxyd of manganese, which is found in abundance in the earth, is commonly used. One part of it is put into a retort, and 4 parts of muriatic acid, diluted with an equal weight of water, is poured upon it. An effervescence is produced; and, by the application of a moderate heat, a gas is discharged, formed from the combination of the muriatic acid with part of the oxygen of the oxyd of manganese. The process is more economical, when the materials from which the common muriatic acid is obtained are merely mixed with manganese: 3 parts of muriat of soda, mixed with 1 part of the black oxyd, are put into a retort, and 2 parts of sulphuric acid, diluted with $1\frac{1}{2}$ part of water, are poured upon the mixture. A moderate
heat

heat is applied ; the sulphuric acid combines with the soda of the muriat of soda ; and the muriatic acid disengaged, attracting the oxygen of the metallic oxyd, forms the oxygenated muriatic acid.

It exists in the state of permanent gas ; by causing it to pass through water placed in the receivers connected with the retort, the liquid oxygenated muriatic acid is obtained. The combination of the oxygen with the muriatic acid in this process, it has justly been observed by Vauquelin, is not the effect of the simple attraction exerted between them ; but of that attraction, promoted by the disposing affinity of the manganese to combine with the muriatic acid, in a less perfect state of oxydation than that in which it exists in the black oxyd.

Oxygenated muriatic acid is a gas permanently elastic ; when water is saturated with it, the compound indeed becomes concrete, or crystallizes, but the pure gas itself cannot be condensed. It is heavier than atmospheric air ; is of a yellow colour, with a tinge of green ; and of all the gases is most noxious to animal life : even when diluted with a large quantity of atmospheric air, it occasions a difficulty of breathing, and a severe sense of stricture at the breast, which renders it impossible

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to make a full inspiration ; and these symptoms, often accompanied with others, continue for a considerable time.

Though so noxious to life, this gas does not extinguish combustion ; it is even capable of inflaming several substances at a moderate temperature. This is the case with phosphorus, sulphur, and many of the metals ; and when a burning taper is introduced into it, it burns more vividly than in atmospheric air. It also decomposes ammoniacal gas with inflammation. In order that these effects may be fully obtained, it is necessary that the gas should be pure, and that its temperature should be above 70° of Fahrenheit. These experiments clearly prove, that the repulsive power of caloric is frequently more powerful than even a chemical affinity in counteracting combination, since substances burn in this acid gas at a lower temperature than they do in pure oxygen gas.

Oxygenated muriatic acid gas, mixed with hydrogen, renders it capable of being inflamed by the electric spark ; added to the nitrous gas, it converts it into nitrous acid, and sulphureous into sulphuric acid.

This

This acid combines with water, though in much less quantity than the simple muriatic acid, the water not taking up above twice its bulk. When the water is fully saturated with it at a low temperature, the combination becomes concrete. The solution has a yellow colour, a styptic bitter taste, and a very suffocating odour. The gas is easily expelled from it by heat; by light, it is decomposed, the oxygen of the oxygenated acid being separated.

This liquid acid has nearly the same relations to the other chemical agents, as it has in the state of gas. It oxydates the inflammables and the metals, and passes to the state of simple muriatic acid. These oxydations are not accompanied with the extrication of hydrogen; because the metal receives its oxygen, not from the water, but from the acid. As the oxygen is retained in the oxygenated muriatic acid by a very weak attractive force, even those metals that have the weakest attraction to it are oxydated.

The most remarkable and important property which this acid possesses is that of destroying the vegetable colours. It renders almost every kind of vegetable matter perfectly white, and, from this

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property,

property, has been applied to the art of bleaching with the greatest advantage. It is to Berthollet principally that we are indebted for this successful application of chemical science.

In this method, the common process of bleaching is imitated, substituting the application of the dilute acid for exposure to the air and light. The cloth is exposed alternately to the action of an alkaline ley and of this diluted acid, till the colour is discharged; it is washed with soap; is immersed in very diluted sulphuric acid, by which the whiteness is improved; and is, lastly, exposed to the air for a few days, to carry off completely the smell of the oxygenated acid. In place of the pure acid diluted with water, a liquor, in which it is condensed by potash or lime, is now generally used, as being much less offensive to the operator.

The theory of the action of the oxygenated muriatic acid in bleaching, as stated by Berthollet, is simple and satisfactory. It is perfectly analogous to the same process conducted by exposure to air, water, and light. The end obtained by either is the combination of oxygen with the colouring matter of the vegetable; the colour is thus nearly destroyed, and the matter

ter on which it depends is at the same time rendered soluble in the alkaline solution. Hence the necessity of the alternate application of these two agents, the one removing what the other has rendered soluble, and which, although whitened, would in time regain part of its colour. The only difference between the two processes is, that in the one the oxygen is presented in a much more concentrated state than in the other, and therefore produces the same effect in a much shorter time. In the subsequent steps, the washing with soap removes the disagreeable smell of the oxygenated acid, and gives a glossy appearance to the cloth; and the diluted sulphuric acid improves its whiteness, by dissolving the small portion of iron and calcareous earth in the thread, and any colouring matter that may have resisted the action of the alkali.

Oxygenated muriatic acid combines with the alkalis and earths, forming neutral salts, termed Oxygenated Muriats, or Oxy-muriats, and which differ entirely in their properties from the common muriats. They are particularly distinguished by affording very pure oxygen when exposed to heat, and by deflagrating, or detonating violently with inflammable substances, by mere friction. The
oxygenated

oxygenated muriatic acid gas displaces the carbonic acid from the alkaline carbonats; the liquid acid does not, but forms a kind of triple salt.

OXYGENATED MURIAT OF POTASH.—To prepare this salt, the usual materials for preparing the oxygenated muriatic acid are put into a retort, connected with Woulfe's apparatus. An alkaline solution is prepared by dissolving 4 parts of sub-carbonat of potash in 20 parts of water, abstracting its carbonic acid by quicklime, and filtering the liquor. This solution is put into the receivers, the first being left empty, and they are carefully luted. On heat being applied to the retort, the oxygenated acid is disengaged, and, being made to pass through the liquor, combines with the alkali.

It is singular, that the oxygenated muriatic acid does not combine directly with the alkali, but suffers a partial decomposition. One part of it passes to the state of muriatic acid, and forms muriat of potash; the other part receives the oxygen with which the former parted, and combines with another portion of alkali, forming a salt, in which the acid exists with a larger proportion of oxygen than it contains in its usual state of oxygenated acid. This salt, therefore, is, properly speaking, not an oxygenated

oxygenated muriat, but a *hyper-oxygenated muriat of potash*. These apparently singular combinations seem to be owing, as Vauquelin has remarked, to disposing affinities, to the stronger attraction of the alkali to muriatic, than to oxygenated muriatic acid, assisted by the attraction which the latter has for a still larger portion of oxygen.

The hyper-oxygenated muriat being much more sparingly soluble in water than the common muriat, is deposited in small crystalline plates, towards the end of the process. To obtain it perfectly pure, it may be dissolved in boiling water, this solution crystallizing on cooling. These crystals are neither deliquescent nor efflorescent; they are soluble in 17 parts of cold, in $2\frac{1}{2}$ of boiling water. The taste of the salt is cool and penetrating; it is free from the odour of the acid, but retains its power of destroying the vegetable colours, though when added in a small proportion, many of these colours are rather heightened. Exposed to heat, it is first fused, and then decomposed; pure oxygen, amounting to half its weight, being given out, when the bottom of the vessel is heated to redness. Part of its oxygen is also disengaged by mere friction. The acids decompose it, disengaging a large quantity of oxygenated muriatic acid,
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with decrepitations and slight flashes of light, and with an explosion, if heat is applied.

The mutual action of this salt, and inflammable substances, is extremely violent. When one or two grains of it are mixed with half the quantity of sulphur & of charcoal, and merely triturated, a violent detonation is produced. Similar effects are produced from triturating it with other inflammable substances, or with the metals; in some cases, even more violent, and in all of them so much so, that the experiment cannot be safely made with more than two or three grains. When these mixtures are struck with a hammer, the detonation, being more sudden, is more violent, and is often accompanied with a flash of light. They are likewise inflamed by sulphuric, and some of them by nitric acid, with less detonation, but with more light.

These violent actions depend on the very large quantity of oxygen which this salt contains, and which it retains by a weak attractive force.—When triturated with an inflammable body, or when the mixture is struck, this oxygen is conceived to be brought by the pressure into closer contact with the particles of the inflammable substance

stance; an instantaneous combination of them is effected; and the product of the combination being either a gas or a substance forced into the gaseous form by the large quantity of caloric suddenly extricated, — this striking on the surrounding atmosphere is the cause of the report. When an acid is dropped on these mixtures, oxygenated muriatic acid gas is disengaged, but being presented in its nascent state to the inflammable matter present, the latter attracts its oxygen, and the same effect is produced, less violent indeed, because more successive.

OXYGENATED, or HYPER-OXYGENATED, MURIAT OF SODA resembles that of potash in the greater number of its properties. It differs from it in being crystallized with difficulty, in its crystals being deliquescent and soluble in alcohol.

The combination of oxygenated muriatic acid with Ammonia cannot be formed; as when the acid is added, the ammonia is decomposed.

NITRO-MURIATIC ACID.

This is a compound acid, similar to the oxygenated muriatic. It is formed by adding one part of
muriatic

muriatic acid to two parts of nitric; the former attracts part of the oxygen of the latter, which is thus converted, partly into nitrous acid and partly into nitrous gas, while the muriatic becomes oxygenated. This decomposition, according to the remark of Vauquelin, is the effect of concurring affinities, of that of the muriatic acid to oxygen, and that of the nitric acid to nitrous gas. The compound produced is a mixture or combination of oxygenated muriatic, and nitrous acids; and when saturated with an alkali or earth, affords the salts which these acids form. In its properties it resembles the oxygenated muriatic. It is used principally in the arts as the solvent of gold.

Seçt. II. — — FLUORIC ACID.

THIS is the second of the acids whose composition is unknown. It was discovered by Scheele. Combined with lime, it forms a fossil, known to mineralogists by the name of Fluor Spar, and hence it was named the Fluoric or Sparry Acid. To obtain it, one part of sulphuric acid is added to an equal weight of fluor spar coarsely powdered, and a moderate heat applied: the sulphuric acid exerts a stronger attraction to the lime; the
fluoric

fluoric is disengaged, and assumes the gaseous form. This gas is heavier than atmospheric air; it has a pungent, suffocating odour; is incapable of supporting combustion; is absorbed by water, and possesses all the general properties of acids. The watery solution retains these properties, is caustic, and when saturated emits white fumes.

The distinguishing property of this acid is its power of dissolving siliceous earth, which resists the action of every other acid. This earth is dissolved by it very rapidly, and is retained in a state of combination, while it exists in the state of gas;—but the contact of water precipitates the whole or the greater part of it, forming a crust, or precipitate, the gas being absorbed. The saturated watery solution of the acid is likewise capable of dissolving the earth. From this property, leaden vessels must be used in preparing and preserving it, siliceous earth being an ingredient of glass.

The action of this acid, either in the state of gas or combined with water, upon the inflammable substances or upon the metals, is very inconsiderable, as it cannot afford to them oxygen.

It combines with the alkalis and earths, forming salts, termed Fluats. They are generally deliquescent, and not easily crystallized. They are decomposed by the sulphuric, nitric, and muriatic

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acids

acids; and the alkaline fluats are also decomposed by lime. They act upon siliceous earth; the earth, alkali, and acid, forming a triple compound. — FLUAT OF POTASH is very soluble in water, and its solution may be evaporated to the consistence of a jelly, without obtaining any distinct crystallization; it is melted and decomposed by heat. — FLUAT OF SODA has similar properties: it is rather less soluble in water, and decrepitates on exposure to a red heat. — FLUAT OF AMMONIA forms a gelatinous solution in water, which deposits small crystals that are deliquescent: they are melted by heat, and sublimed with partial decomposition.

Sect. III. — — BORACIC ACID,

THIS is the last of the undecomposed acids. It does not exist in great quantity in nature. The combination of it with soda is a native production, dug in an impure state from the bottom of certain lakes in Thibet. When purified, it forms the borax of commerce; and it is from this salt that the boracic acid is obtained. Any quantity of it is dissolved in hot water; and sulphuric acid is added, till the solution has an acid taste: as it cools, white scales are deposited. These are the boracic acid; they are washed with cold water,

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to carry off any adhering sulphuric acid, or sulphat of soda, and are again crystallized. It may likewise be obtained by sublimation, from 2 parts of borax, 1 of sulphuric acid, and 1 of water.

Boracic acid is in the form of brilliant white scales, soft and somewhat unctuous to the touch. Its taste is bitterish, with a slight degree of sourness; it reddens the vegetable colours; is soluble in 20 parts of cold, and 5 of boiling water; it is soluble in alcohol, which it causes to burn, when kindled, with a green flame; it is fused by heat into a perfect glass, without undergoing any other change: it is not volatilised by the most intense heat; but if heated with water, is carried up by its attraction to the aqueous vapour.

Boracic acid combines with the alkalis and several of the earths, forming salts, termed Borats. These communicate a green colour to the flame of alcohol: they are decomposed by almost all the acids in the humid way; but in the dry way, at a high temperature, the boracic acid is able from its fixity, to decompose the salts which several of these acids form. It has a stronger attraction to the earths than to the alkalis.

BORAT OF POTASH.—Its properties are little known. It has a tendency to attract an excess of alkali; is soluble in water, affording, by slow evaporation

poration, prismatic crystals, which are not changed by exposure to the air. It is vitrified by heat.

BORAT OF SODA.—This salt, when perfectly neutral, cannot be crystallized. When it has an excess of alkali, it forms the borax of commerce, which is a native production. The taste of borax is cool, and somewhat alkaline, and it changes the vegetable colours to a green. It is soluble in 12 parts of cold, and in 6 parts of boiling water: exposed to heat, it undergoes the watery fusion; and by a stronger heat is vitrified without decomposition. According to Bergman, it consists of 34 parts of acid, 17 of soda, and 49 of water.

BORAT OF AMMONIA can hardly be obtained in the solid state; as when ammonia is saturated with boracic acid, on evaporating the solution, the greater part of the ammonia is expelled. By spontaneous evaporation a salt has been obtained in small prismatic crystals, having a sharp taste, and changing the vegetable colours to a green, evidently containing, therefore, an excess of alkali.

Boracic acid scarcely acts upon the metals, but may be combined with their oxyds.

END OF VOLUME I.